Department of Defense
Legacy Resource Management Program

PROJECT NUMBER 05-158

Grand Bay-Banks Lake Stewardship Partnership - Phase II

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November 2006

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE **NOV 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Grand Bay-Banks Lake Stewardship Partnership - Phase II**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Ofc Deputy UnderSecretary of Defense for Installations & Environment,Department of Defense Legacy Resource Management Program,3400 Defense Pentagon,Washington,DC,20301-3400**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**228**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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Acknowledgements

The Grand Bay-Banks Lake Stewardship Partnership Phase II Final Report (Legacy #05-158) was funded by the Department of Defense Legacy Resource Management Program.

Executive Summary

Site Overview

The Grand Bay-Banks Lake ecosystem are major parts of an expansive palustrine wetland complex (over 18,000 acres) in south-central Georgia in Lanier and Lowndes Counties near Valdosta. The wetland is co-owned by Moody Air Force Base (AFB); Georgia Department of Natural Resources (DNR), Grand Bay Wildlife Management Area (WMA); U.S. Fish and Wildlife Service (USFWS), Banks Lake National Wildlife Refuge; and The Nature Conservancy (TNC). The site contains excellent examples of pine flatwoods, evergreen hammocks and an interconnected network of Carolina bays that form Georgia's second largest wetland complex. These diverse communities provide habitat for several rare species including Bald Eagles, Peregrine Falcons, Wood Storks, Sandhill Cranes, round-tailed muskrats, indigo snakes and gopher tortoises.

Project Description

Hydrology and fire are the two underlying components that drive most ecosystems in the Southeastern United States. Therefore, a better understanding of these underlying processes that impact the biodiversity of Grand Bay-Banks Lake (GBBL) will be of substantial benefit. The Department of Defense Legacy Resource Management Program has funded, under the direction of partnership coordinator (The Nature Conservancy), the development of preliminary hydrological and fire management plans for the area as well as a monitoring plan to track the impacts of management action or inaction on the rare species and natural communities found at GBBL. Other components of this project include mapping of current and historic vegetation at the site, and a description of the presettlement fire regime and vegetation of the GBBL area.

Project Results

The current and historic vegetation mapping project conducted a change analysis that confirmed the opinions of experts familiar with the site (see Appendix C for list of experts). In the absence of frequent fire, the Carolina bays are shifting from open marsh communities to scrub-shrub communities. This is resulting in a decrease in habitat needed for rare species at GBBL. A study of the presettlement fire regime confirmed that fire was once a frequent occurrence in portions of the wetland complex at GBBL. A hydrological study provides information on the connection between the surface water and groundwater at the site and recommends management options to meet ecological goals. The fire management plan make recommendations on how to increase the frequency of fire at the site to return GBBL to a larger percentage of open marsh communities, similar to levels observed in the past.

INTRODUCTION

The 100,000 acres that encompass the Grand-Bay-Banks Lake (GBBL) ecosystem in southern Georgia contain an abundant diversity of relatively undisturbed aquatic and terrestrial habitats. These unique communities include excellent examples of pine flatwoods, evergreen hammocks and an interconnected network of Carolina bays that form Georgia's second largest wetland system. These diverse communities provide habitat for several rare species including Bald Eagles, Peregrine Falcons, Wood Storks, Sandhill Cranes, round-tailed muskrats, indigo snakes and gopher tortoises. In total, 27 species of special concern occur on Moody Air Force Base (AFB), and several additional species may well be found outside installation boundaries. Sandhill Cranes and round-tailed muskrats are in decline due to the loss of habitat caused by the lack of fire and altered hydrology within the GBBL ecosystem.

The Grand Bay-Banks Lake Stewardship Council is a collaboration among Moody AFB, The Nature Conservancy (TNC), Georgia Department of Natural Resources (GA DNR), U.S. Fish and Wildlife Service, (USFWS), Georgia Department of Transportation (GaDOT) and numerous private landowners. The mission of the partnership is to develop and implement a voluntary and cooperative stewardship plan for the GBBL Ecosystem. The goal of the plan is to ensure the long-term viability of the native plants and animals, and ensure the integrity of the ecosystems, while providing for compatible human uses. The project area for this plan is lands owned by the Council, within the Council boundary.

Previous Work

In 2003, using funds from the Department of Defense Legacy Program and the Price-Campbell Foundation, a comprehensive Site Conservation Plan (SCP) was completed for Grand Bay-Banks Lake. The SCP establishes conservation targets and includes a threats analysis and strategies to mitigate the threats on the conservation targets. The GIS-based analysis identified stresses and sources of stress for each of six conservation targets. From this analysis, the following top three conservation strategies were developed: 1) Enhance or restore essential habitat for species of special concern; 2) Prohibit additional residential, commercial, and agricultural development within 150 meters of wetlands / rivers; and 3) Collaborate with neighboring landowners to promote and establish conservation easements and to promote habitat protection. Implementation of these strategies will require the combined effort of all council members, as well as public commitment to the conservation of this unique ecosystem. A literature review of the biotic and abiotic needs of the conservation targets was conducted to support the SCP and future management planning. Another key component that was completed in 2003 was additional rare species inventories and a qualitative analysis of biologically significant natural communities in and around Moody AFB. An extensive GIS database was compiled that includes land ownership, soils, agricultural and forest management data, pollutant data, land cover and land use data layers.

In June 2004, a meeting was convened to discuss the Desired Future Ecological Condition for GBBL (see Attachment C for meeting summary and list of attendees). Desired future ecological condition is defined as a clearly articulated, broad to specific

expression of ecosystem conditions, attainable within the human context over the next fifty years, used to guide management and land use. Most simply, a desired future condition is a management goal, the conditions that management is attempting to obtain over a set period of time. It was determined that much more information was needed to clearly articulate management goals for GBBL. The greatest needs were to: 1) map the current vegetation; 2) compare the current vegetation to historic vegetation and conduct a change analysis and 3) conduct a hydrologic study to learn more about water flow through the system. This final report contains the results of a project funded by the Department of Defense Legacy Resource Management Program to meet these needs.

Project Area

The Grand Bay-Banks Lake (GBBL) ecosystem includes the following large wetland complexes: Grand Bay, Moody Bay/Rat Bay, Oldfield Bay and Banks Lake. The study area selected for this study focused on the wetland systems plus an upland buffer, and includes approximately 30,000 acres. The study area is bounded to the east by U.S. Highway 221, Knights Academy Road to the south, and GA Highway 125 to the west. The northern boundary of the GBBL study area approximately follows U.S. Highway 129, and was chosen to capture agricultural land potentially important for Sandhill Cranes.

Grand Bay-Banks Lake Strategic Plan

Comprehensive Mission Statement
To ensure the long-term viability of the native plants and animals and the integrity of the Grand Bay-Banks Lake ecosystem, while providing for compatible human uses.

Statement of Need
Hydrology and fire are the two underlying components that drive most ecosystems in the Southeastern United States. Therefore, a better understanding of these underlying processes that impact the biodiversity of Grand Bay-Banks Lake (GBBL) will be of substantial benefit for the Air Force. The Department of Defense Legacy Resource Management Program has funded, under the direction of partnership coordinator (The Nature Conservancy), the development of preliminary hydrological and fire management plans for the area as well as a monitoring plan to track the impacts of management action or inaction on the rare species and natural communities found at GBBL. These plans form the three components of the GBBL Strategic Plan. An examination of the presettlement fire history and vegetation patterns provide background information for the plan and are included as Appendices to the Final Report (of which this strategic plan is a part). These component plans are meant to be iterative in nature and will be modified as management strategies are implemented and evaluated.

Next Steps
Grand Bay-Banks Lake is owned and managed by GA DNR, the Department of Defense, US Fish and Wildlife Serve, The Nature Conservancy and the GA Department of Transportation, as well as numerous private landowners. The Department of Defense is required by federal and state regulations to be proactive stewards of the natural resources of its installations. However, natural resources do not confine themselves to installation boundaries. Nor do mission activities such as aircraft flights, occur exclusively within property lines.

Nowhere is this more apparent than with the ecological processes of the hydrology and fire – the focus of this project. The waters that impact Moody AFB, may originate hundreds of miles away, yet impact the installation. Likewise, waters flowing though Moody AFB later make their way to other users. Fire also impacts much more than the training that occurs on Moody AFB; it also impacts the surrounding landowners and citizens of the area.

Recognizing that installations are indeed part of their surrounding ecosystems, DoD has mandated the adoption of an ecosystem management approach and has encouraged cooperation with neighboring partners to accomplish mutually beneficial goals. The information gathered during the project will result in such an ecosystem management process at Moody AFB. Beyond Moody AFB, data gathered can also be used by other DoD resources managers to develop their ecosystem management efforts, ecological processes examined in this project impact other installation across the southeast.

Grand Bay-Banks Lake Strategic Plan
Hydrology Component

Preliminary Hydrologic Evaluation of the Grand Bay and Banks Lake Area near Moody Air Force Base, Valdosta, Georgia

David W. Hicks and Brian A. Clayton

INTRODUCTION

Grand Bay and Banks Lake are major parts of an expansive palustrine wetland complex in south-central Georgia in Lanier and Lowndes Counties near Valdosta. The wetland is co-owned by Moody Air Force Base (AFB); Georgia Department of Natural Resources (DNR), Grand Bay Wildlife Management Area (WMA); U.S. Fish and Wildlife Service (USFWS), Banks Lake National Wildlife Refuge; and The Nature Conservancy (TNC).

Expansive palustrine wetlands require frequent fire to prevent the invasion and growth of dense understory vegetation that reduces the ecologic function of the wetland. In addition, the dense understory encourages the nesting of bird populations that create a hazard to air craft. The northwestern part of the wetland is adjacent to Moody AFB and underlies their runway approach, and birds flying in the wetland area could damage low flying aircraft. Typically, wetland fires burn for extended periods of time and produce significant dense smoke as a result of the peat layer that develops from organic decay of vegetation. Dense smoke significantly limits the ability of aircraft to utilize the Moody AFB facility and, thus, could jeopardize the execution of their defense and training missions.

The natural hydrology of the interconnected wetlands has been altered by the construction of sills (crash trails) that both provide emergency access throughout the wetland, but also control the overland flow of water within the wetland complex. Little is known regarding the drainage patterns within the wetland complex and the effects of flow manipulation between the partitioned wetland bays. In addition, it is possible that a shallow, locally extensive, aquifer may provide a variable source of water to portions of the wetland. In cooperation with Moody AFB, Georgia DNR, the USFWS, and TNC, the Joseph W. Jones Ecological Research Center conducted a short-term hydrologic investigation from March until October 2006 in the Grand Bay and Banks Lake area to expand our understanding of the hydrologic system, and provide information that may allow resource managers to use the interplay of hydrological manipulation and fire to achieve long-term ecological management goals.

Purpose and Scope

The purpose of this report is to present the results of a short-term study of the hydrology of a palustrine wetland and shallow groundwater system in the Moody AFB area near Valdosta, Georgia. The specific objectives of the study were to (1) describe the hydrologic response of the various wetland bays to rainfall; (2) define the effects the sills have on the flow of wetland water throughout the system; (3) evaluate the potential for groundwater and surface water interaction between the surficial aquifer and the wetlands; and (4) determine if the control structures located within the sills may be used to manipulate the overland flow of wetland water as a fire management tool.

This report describes the general shallow geology of the study area, the observed fluctuations in wetland water levels, the general water quality conditions in selected wetlands as well as ditched surface-water inflow canals; the possibility for groundwater and surface water interaction, and the potential for the wetland bays to be used for hydrologic manipulation to achieve long-term ecological management goals through fire management. Maps are provided showing the hydrologic gradient between bays and the directions of flow of wetland water.

Description of the Study Area

Grand Bay and Banks Lake are located in the lower Coastal Plain physiographic province in what is typically known as "flatwoods" (figure 1). This wetland group comprises the major part of an 18,000-acre wetlands system, which is the second largest natural blackwater wetland in the Coastal Plain of Georgia (The Nature Conservancy). In many ways, the large, shallow, peat-filled wetlands of Grand Bay mimic their big brother, the Okefenokee Swamp. Grand Bay and Banks Lake are land features known as "Carolina bays". The bay wetlands are found along the Atlantic coast within coastal Delaware, Maryland, New Jersey, North Carolina, South Carolina, Virginia, Georgia, and north central Florida. They are also found within the northern Gulf of Mexico coastal plain within southeast Mississippi, Alabama, and southwest Georgia where they are called "Grady Ponds" because of the Grady soils that are typically found beneath the wetlands. The Carolina bays are generally oval-shaped depressions and vary in size from one to several thousand acres. They are named for the bay trees that are frequently found in them, not because of frequent ponding of water.

Plant communities within these bays are a mosaic of wet savannas, shrub bogs, cypress-gum ponds, prairie and black gum-cypress swamps, practically indistinguishable from habitats found in the Okefenokee. The diversity of wildlife is also comparable with that found in the Okefenokee. Uplands surrounding the wetlands provide good examples of mature longleaf-slash pine flatwoods. A small percentage of the area is in mixed live oak-pine and is home to gopher tortoises and indigo snakes. Dudley's Hammock, a rare example of a mature broadleaf-evergreen hammock community, is found in the area (The Nature Conservancy). The bays have many different vegetative structures based on the depression depth, size, hydrology, and subsurface.

The topography of the study area is characterized by low, rounded hills and land surface elevations that range from about 250 to 185 ft above sea level (ASL). The topographic high for the study area is near Bemiss on the southeastern side of Grand Bay.
Karst is the dominant land form in the study area, which is marked by sinkholes, sinkhole lakes, and sparse surface drainage. The development of karst topography is dependent on circulating groundwater dissolving the underlying limestone. As the limestone dissolves, large solution openings, cavities, and caves are formed. During periods of very low groundwater levels, the normally water-filled voids in the limestone are de-watered and the roofs of the features lose the support provided by the buoyancy effect of the water. When the support for the overlying sediments is removed, collapse occurs at the surface,

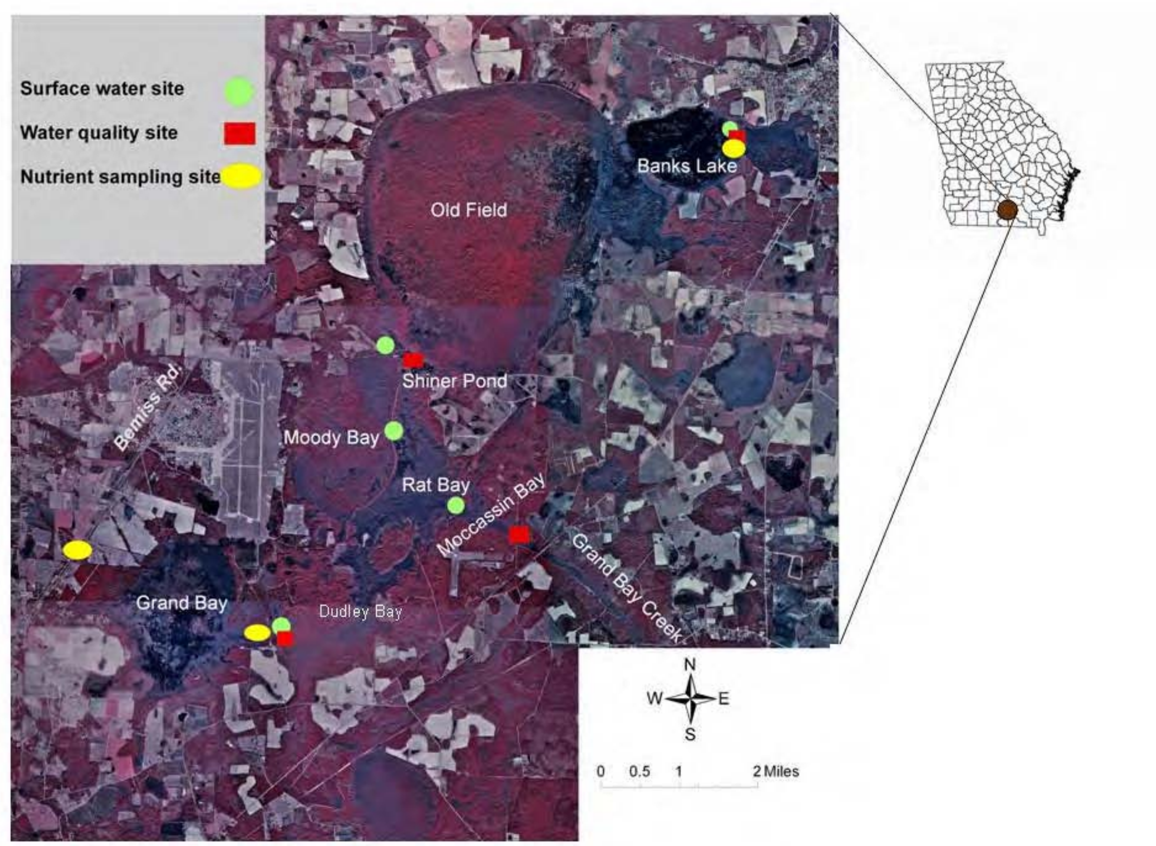


Figure 1.—Location of the study area and monitoring sites.

and sinkholes and sinkhole lakes are formed. Active sinkholes are not common in the study area, however, the lakes and wetlands produced by paleo-solution of the underlying limestone formations is a significant portion of the landscape. The dominant topographic features in the study area are the wetlands, bogs, and lakes such as Grand Bay and Banks Lake that are believed to have developed as a result of large scale dissolution of the underlying limestone formations. However, the origin of the Carolina Bays has been a topic of considerable controversy. The most popular theory is that the bays formed as a result of cometary collisions; although this theory is not data supported.

The bays are especially rich in biodiversity, including some rare and/or endangered species. Species that thrive in the bays' habitat include birds, such as wood storks, herons, egrets, and other migratory waterfowl, mammals such as deer, black bears, raccoons, skunks, and opossums. The most common trees are black gum, bald cypress, pond

cypress, sweet bay, loblolly bay, red bay, sweet gum, maple, magnolia, pond pine, and shrubs such as fetterbush, clethra, sumac, button bush, zenobia, and gallberry (The Nature Conservancy).

Previous Investigations

The hydrology of the Valdosta area has been studied, in part, since 1898 when McCallie first published the results of investigations he conducted in the Coastal Plain of Georgia. Other researchers such as Stephenson and Veatch (1915), Warren (1944), Herrick (1961), Herrick and Vorhis (1963), and Miller (1986) studied the Valdosta area at a very limited scale. A very comprehensive study was conducted by Krause (1976, 1979) who examined groundwater and surface water interactions in the area proximate to the Withlacoochee River and identified areas within the Upper Floridan aquifer where the influx of river water resulted in water quality problems in the aquifer. McConnell and Hacke (1993) conducted an extensive water quality study in the Valdosta area. They built on the work of Krause and better defined the interplay of river water and groundwater, and developed maps showing aquifer areas showing areas where groundwater development should be avoided based on water quality. The hydrology of the Grand Bay and Banks Lake area is not included in any of the previous studies.

Acknowledgments

Appreciation is extended to Mr. Tip Hon, Georgia DNR, retired, who provided invaluable information on the Grand Bay and Banks Lake wetland, and direct support during the field study. His contributions both written and oral were essential in advancing our understanding of this complex hydrologic system. The authors appreciate the support of Moody AFB personnel, in particular Mr. Greg Lee and Mr. Mike Burton for supplying critical information collected on the Moody site, as well as coordinating access to the Moody AFB property. A special thanks to the U.S. Fish and Wildlife Service for allowing the installation of monitoring equipment on their dock in Banks Lake. The authors would also like to thank The Nature Conservancy for providing Department of Defense Legacy Resource Management Program funding to conduct this investigation.

METHODS of INVESTIGATION

A thorough data search was conducted from published literature. Site-specific data were provided by Shaw Environmental Inc., from previous work conducted on Moody AFB as a part of their environmental studies. Significant data were also provided by Mr. Tip Hon, Georgia DNR (retired), from his personal library. In addition, Mr. Hon provided valuable historical information on the hydrology of the bays.

Field visits to the wetlands were conducted and five control-structure sites were selected for the installation of continuous water-level monitoring stations. The locations were verified using topographic and digital GIS aerial land coverage maps. Water-level recorders were installed on dikes adjacent to Grand Bay, Rat Bay, Old Field Bay (Shiner Pond), and Moody Bay. Platforms were constructed at the four wetland sites and Ott Thalimedes data loggers were installed in 6-inch diameter stilling wells attached to the

platforms. At Banks Lake a stilling well was attached to an existing dock and equipped with an Ott data logger. The Ott encoder unit is activated by a float-cable-counterweight system that is driven by the rise and fall of the water surface. The rotation action of the pulley is converted to an electrical signal by the instrument, and is stored at 1-hour time intervals on the logger. The instruments were checked monthly and water-level data were downloaded to a laptop computer via an infrared reader. Instrument readings were quality controlled with a manual tape down measurement at the time the data are downloaded. Wetland water-level data have been collected since May 2006 at the four wetland sites and since August at Banks Lake.

Continuous water quality data were collected at selected sites in the study area where automated water quality monitors were installed. YSI 6600EDS (Extended Deployment System) water quality probes were installed at four sites: Grand Bay, Old Field Bay (Shiner Pond), Grand Bay Creek, and Banks Lake. The instruments were deployed in a 4-inch diameter PVC pipe which has 1.5-inch diameter holes to allow water movement. The pipes were attached vertically to the wooden platform at Grand Bay, on the water control structure at Shiner Pond and Grand Bay Creek, and on an existing dock at Banks Lake. The instruments were configured to measure temperature, specific conductivity, pH, dissolved oxygen, and turbidity at 1-hour intervals. The probes were calibrated every 2 months for all parameters in compliance with the design protocol. Data were downloaded monthly to a laptop computer using Ecowatch software.

Grab samples were collected from three sites: Bemiss Road, Grand Bay, and Banks Lake. Triplicate samples were taken at each site in 1-liter polypropylene bottles. Samples were transported to the lab on ice and filtered (Fisher brand, TCLP filter, 47MM, 0.7 micron pore size) within 24 hours. Following filtration the water was frozen until the samples were analyzed which was within 2 months from collection. Samples were analyzed using a Lachat Quickchem 8000 to determine nitrate and phosphorus concentrations.

Climate data were obtained from The University of Georgia, Georgia Automated Environmental Monitoring Network (www.georgiaweather.net). Precipitation data were obtained for the Moody AFB National Weather Service site (NOAA, written commune., 2006).

Climate

The average rainfall in the study area is about 53 inches/year (figure 2). With a dynamic weather pattern, precipitation totals vary depending on climatic conditions. The close proximity to the Atlantic and Gulf coast creates opportunities for moisture from tropical systems and sea breeze inducted thunderstorms during the summer months. June (5.50 in.), July (6.94 in.), and August (6.20 in.) have, on average, the highest monthly precipitation totals (NOAA, written commune., 2006). As a result of a very dry spring, cumulate rainfall for March, April, and May was more than 6 inches below normal. Tropical Storm Alberto passed thru the area on June 13, dropping nearly 3.0 inches of rain which helped break the minor drought (figure 3).

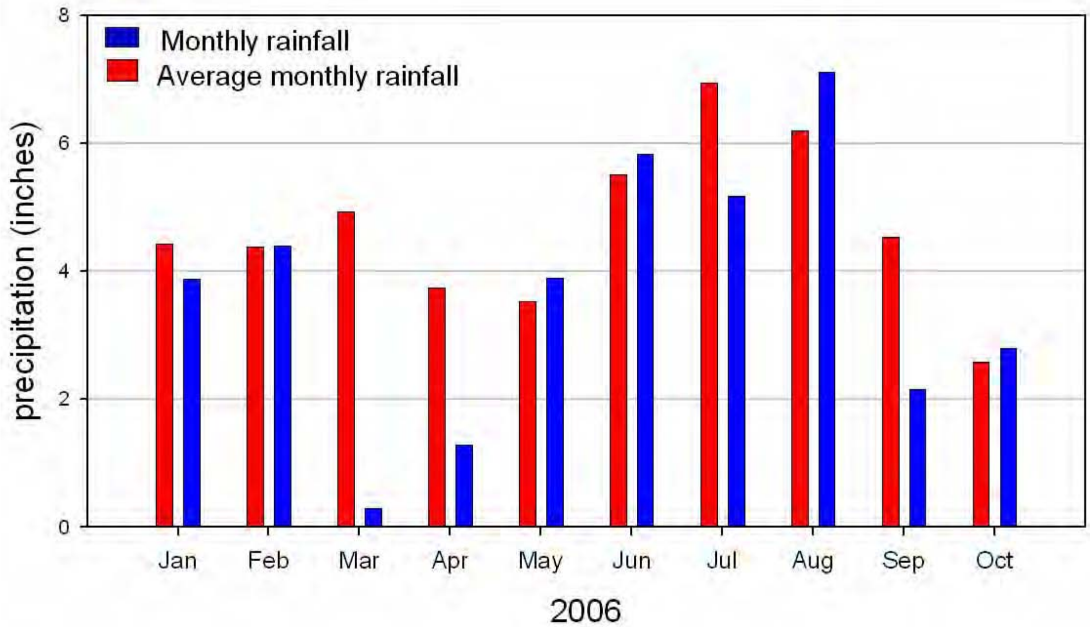


Figure 2.—Monthly rainfall recorded at Moody AFB (data from NOAA).

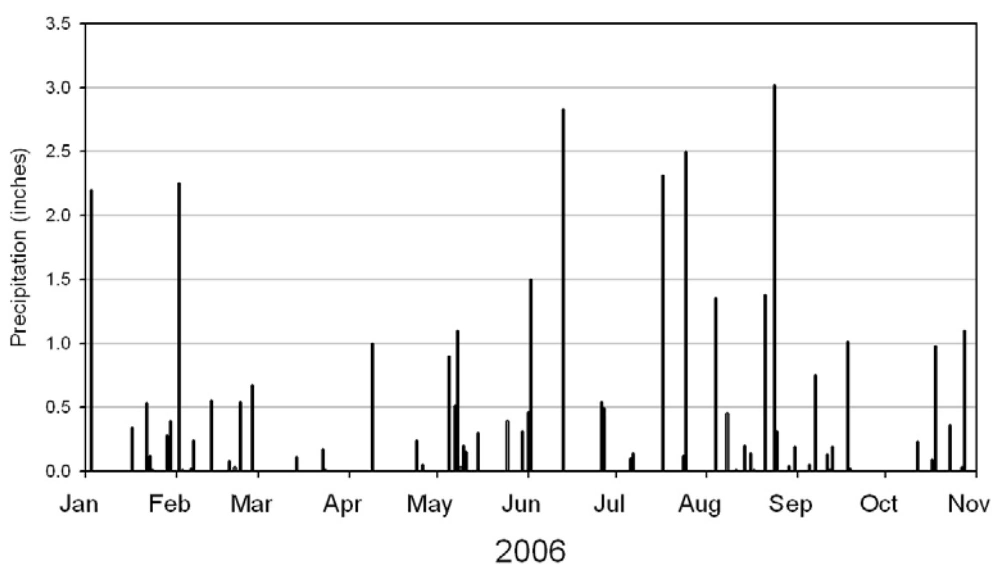


Figure 3.—Cumulative daily rainfall at Moody AFB (data from NOAA).

The yearly average maximum air temperature for the area is 79.1 degrees Fahrenheit. As of November 5, the temperature for 2006 was 1.6 degrees Fahrenheit above average. The air temperature, which is the result of solar radiation, has a strong influence on evapotranspiration rates. Evapotranspiration rates are the highest during the summer months when ambient temperatures are the highest and plant growth is the greatest. During the summer of 2006, the ET losses in the Valdosta area exceeded 0.27 inches/day during several days in June and July.

ET water loss results in a decline in wetland water-levels during the summer months and affects the length of the hydroperiod. As daily temperatures increase wetlands need more abundant rainfall to maintain wetland water-levels. In 2006 the below average rainfall and above average temperatures resulted in a shortened hydroperiod.

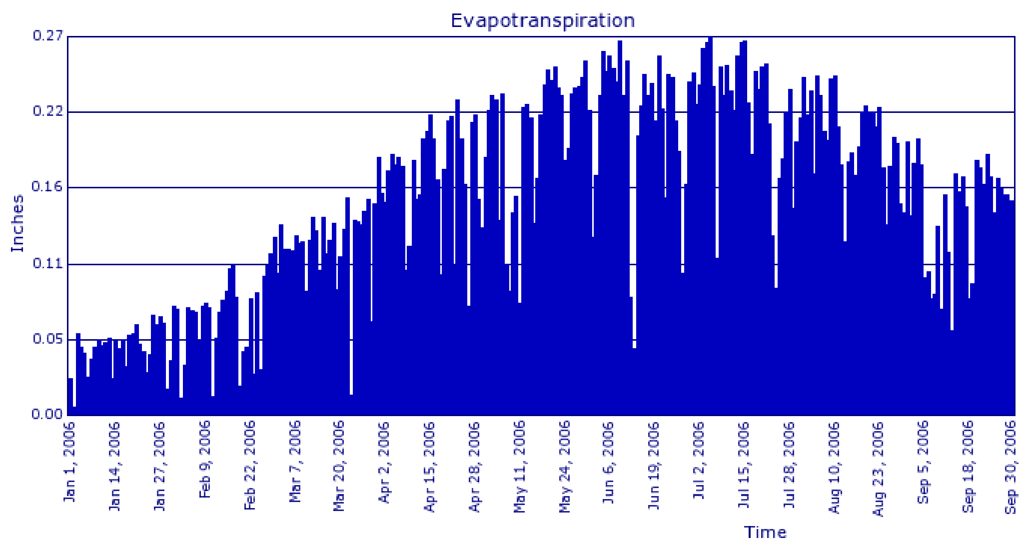


Figure 3.—Evapotranspiration rates in the study area for 2006 (from UGA Peachnet, University of Georgia statewide climatic monitoring network).

GEOLOGIC FRAMEWORK

The study area is underlain by Coastal Plain sedimentary rock to a depth of at least 5,000 ft (Miller, 1986) and by Cenozoic marine sediments to a depth of about 2,000 ft. Only the rocks of Cenozoic age and younger are discussed in this report. These sedimentary formations are, from oldest to youngest: the Ocala Limestone, Suwannee Limestone, undifferentiated rocks of the Hawthorne Group, Miccosukee Formation, and undifferentiated deposits of Quaternary age.

Ocala Limestone

Ocala Limestone of late Eocene age is the basal unit of the Cenozoic-age formations beneath the study area. The top of the Ocala Limestone is at a depth of about 270 ft below sea level (BSL) in the study area where it is about 350-ft thick. The rocks dip

gently to the northeast and gradually thicken in that direction. They consist of white to pale yellow, fossiliferous limestone, and the limestone is interbedded with abundant dolomite; suggesting that following deposition, the formation was exposed to weathering processes for a considerable period of time. According to Krause (1978), the dolomite is secondary in origin, wherein magnesium replaced calcite. In addition, many pre-existing voids in the limestone have been filled with quartz, gypsum, and other evaporite minerals. In many areas, particularly near the major surface-water drainages, the limestone exhibits well-developed secondary porosity as a result of fracturing and subsequent solution of the limestone. The development of deep sinkholes is common along the drainages, as a result of the collapse of solution cavities and caverns within the Ocala Limestone.

Suwannee Limestone

The Ocala Limestone is unconformable overlain by the Suwannee Limestone of Oligocene age. Like the Ocala Limestone, the Suwannee gently dips to the north-northeast and attains a thickness of about 200 ft in the study area. The geologic contact between the Ocala and Suwannee is difficult to identify based on lithology where they both consist of brown to pale yellow, fossiliferous, dolomitic limestone (McConnell and Hacke, 1993). However, the formations can be separated based on the presence of *Asterocycline sp.*, which is an index fossil of the Eocene-age sediments. In general, the Suwannee Limestone consists of layers of brown dolomitic limestone and pale white to yellow fossiliferous, bioclastic limestone; deposits of phosphate and phosphatic limestone are common throughout the formation (McConnell and Hacke, 1993). The rocks of the Suwannee are exposed along sections of the Withlacoochee River from the Georgia-Floridan state line, to within about 8 river miles of U.S. highway 84 near Valdosta (Krause, 1978). Krause also reports that the rocks of the Suwannee Limestone were uplifted by seismic activity during the Miocene period, which has resulted in the Withlacoochee River down cutting through the overlying sediments into the Suwannee Limestone providing for a hydraulic connection in this river section.

Hawthorne Group

Sediments of the Hawthorne Group of Miocene age unconformably overlie the Suwannee Limestone in the study area. In other parts of the Valdosta area, the Hawthorne may be missing as a result of stream erosion or sinkhole collapse. The Hawthorne Group consists of the Chattahoochee, Parachucla, Marks Head, and Coosawatchie Formations (McConnell and Hacke, 1993). The more resistant rocks of the Hawthorne Group are exposed in many low altitude landscapes throughout the region, particularly where the land surface has been lowered by stream erosion.

<u>Chattahoochee Formation</u>

In the study area, the Chattahoochee Formation unconformable overlies the Suwannee Limestone where it is about 40-ft thick. It dips generally to the northeast. The Chattahoochee consists of fairly thin basal layer of quartz sand, overlain by argillaceous, slightly phosphatic, dolomitic limestone. Small blue clasts of clay are common throughout the formation. The basal quartz sand contains breccia made up of angular chert or agate fragments (Krause, 1978) which distinguish the Chattahoochee Formation

from the underlying Suwannee because the dolomitic limestone of the two formations are lithologically similar.

Parachucla Formation

The Parachucla Formation conformably overlies the Chattahoochee. It generally dips to the north-northeast and occurs at a altitude of about 56 ft BSL beneath Moody AFB (Shaw Environmental, Inc. 2005), where it is generally described as a sandy limestone overlain by an 8-ft thick layer of clay.

Marks Head Formation

At Moody AFB, the Marks Head Formation conformably overlies the Parachucla. The top of the Marks Head Formation was encountered at an altitude of 98 ft ASL where it was reported to attain a thickness of about 54 ft (Shaw Environmental, Inc., 2005). McConnell and Hacke (1993) reported that the Marks Head Formation was about 60-ft thick in the Bemiss area where it occurred at an elevation of about 90 ft ASL. In the section of the Withlacoochee River proximate to the study area, the Marks Head has been breached by stream erosion and sinkholes have formed in the streambed which provides a direct hydraulic connection between this formation and the stream. In general, the formation consists of a basal dolostone layer overlain by a 10-ft thick layer of dense clay. The upper part of the Marks Head consists of clayey sand (Shaw Environmental, Inc., 2005). Phosphate is ubiquitous throughout the formation.

Coosawatchie Formation

The Coosawatchie Formation conformably overlies the Marks Head in the study area. The formation is not present in much of the Valdosta area where it has been removed by erosion. At Moody AFB the formation occurs at an altitude of 141 ft ASL and is about 43-ft thick (Shaw Environmental, Inc., 2005). It is reported to be as much as 80-ft thick in the Bemiss area (McConnell and Hacke, 1993); however, it is likely that the formation thickness varies considerably as the result of erosion. In general the formation consists of dense, calcareous clay that has developed as the original carbonate formations weathered.

Miccosukee Formation

The Miccosukee Formation conformable overlies the sediments of the Hawthorne Group. The Miccosukee consists of layers of coarse sand and clay. At Moody AFB the formation occurs near land surface and extends to a depth of about 68 ft below land surface (altitude of 141 ft ASL), and generally consists of poorly graded sand and gravel, and inorganic clay (Shaw Environmental, Inc., 2005). The sand and gravel basal part of the formation is commonly crossbedded and lenticular suggesting that this part of the formation was deposited near shore because it exhibits depositional influences of both continental and near-shore marine environments. The upper part of the Miccosukee Formation is predominantly inorganic clay with pockets of sand and gravel.

Undifferentiated Overburden

At Moody AFB the undifferentiated sediments of Quaternary age unconformably overlie the Miccosukee Formation. They generally consist of thin beds of alluviated sand and

silt in the upland areas and transition into more argillic, hydric soils in the wetlands. Typically, the more permeable upland soils are underlain at a shallow depth with silty, clayey soils of the Miccosukee Formation that are significantly less permeable. At Moody AFB, the permeable undifferentiated sediments are less than 2 ft in thickness and are underlain by the inorganic clay of the Miccosukee Formation (Shaw Environmental, Inc., 2005).

HYDROGEOLOGY

Groundwater can be found beneath the study area in the surficial aquifer, the Miccosukee aquifer (unnamed), the Marks Head aquifer (unnamed), and the Upper Floridan aquifer. The unnamed aquifers that overlie the Upper Floridan are generally not reliable sources of water and, thus, are not used in the study area for a water supply. However, because of their close proximity to land surface, some may be important with regards to lakes and wetlands within the study area. The Upper Floridan aquifer is an extremely important water source and furnishes almost all of the water for domestic, commercial, industrial, irrigation, military, and municipal use in this region.

Surficial Aquifer

The surficial aquifer occurs within the sands and silty sands of the undifferentiated sediments in the upland landscapes. During much of the year, the surficial aquifer contains only pore water stored within the capillary spaces of the soil. When drought conditions persist, which is common in southern Georgia, the surficial soils may become nearly dry. However, when moderate to heavy rainfall is sufficient to saturate the soil column, the infiltrated water is temporarily perched by the underlying clayey sediments of the upper part of the Miccosukee Formation. The perched groundwater slowly moves laterally along the interface between the permeable surface soils and the less permeable clay from the higher elevation recharge areas into the lower elevation discharge areas. It is believed that the lateral flow of locally perched groundwater in the surficial aquifer from upland areas is a major source of recharge to the wetlands in the Grand Bay and Banks Lake system. Although this wetland recharge scenario has been documented in other similar wetland systems, site specific data have not been collected in the study area to define this process.

Miccosukee Aquifer (Unnamed)

McConnell and Hacke (1993) reported that the unnamed aquifer of Pliocene age is present in the basal sand of the Miccosukee Formation. The aquifer is confined above by the clayey upper part of the Miccosukee and below by the Coosawatchie Formation. This aquifer is not regionally extensive and is absent in areas where the surface elevation is less than about 150 ft ASL. Detailed geohydrologic studies conducted on Moody AFB by Shaw Environmental, Inc., have defined thin clay layers separating thicker sand and gravel layers in the lower half of the Miccosukee Formation (Shaw Environmental, Inc., 2005). These clay layers are sufficient to provide vertical confinement within the formation to separate the unnamed aquifer into three distinct water-bearing zones, and in the study area, the aquifer has been divided into surficial, intermediate, and deep zones based on lithology. The water-bearing zones of the unnamed aquifer extend from an altitude of 185 to 141 ft ASL (about 25 to 69 ft below land surface).

Marks Head Aquifer (Unnamed)

The sand and clayey sand of the upper part of the Marks Head Formation are water bearing. The unnamed aquifer is confined below by the clay and dense dolostone in the basal part of the Marks Head Formation and above by the very plastic, inorganic clay of the Coosawatchie Formation. The clay and dolostone layers at the base of the Marks Head Formation are regionally extensive in Brooks, Lowndes, and Lanier Counties and forms a regional aquatard that confines groundwater within this unnamed aquifer. Regionally, the aquifer is reported to range in thickness from about 20 to 36 ft (McConnell and Hacke, 1993). Well logs produced from test wells drilled on Moody AFB show the aquifer to be about 37-ft thick and extend from a depth of 112 to 149 ft below land surface in this area (Shaw Environmental, Inc., 2005). The aquifer can produce well yields up to 50 gallons per minute, and is used in the Lakeland area as an irrigation source for blueberry crops.

Upper Floridan Aquifer

The Upper Floridan aquifer is a regionally extensive groundwater system that is a part of the Floridan aquifer that is a principal source of water supply in Alabama, Georgia, South Carolina, and Florida. In the study area the Upper Floridan aquifer consists of rocks from the Ocala Limestone, Suwannee Limestone, and Chattahoochee and Parachucla Formations of the Hawthorne Group. The rocks of the Suwannee Limestone exhibit well-developed secondary permeability and, thus, generally produce most of the water from the Upper Floridan aquifer. Most wells drilled into the Upper Floridan aquifer in the study area do not extend below the Suwannee Limestone because the high yields obtained from the Suwannee make drilling below it unnecessary (Krause, 1979).

As a result of the well-developed secondary porosity, the aquifer can transmit very large quantities of water. Large interconnected cavities are common in the limestones that make up the aquifer (particularly the Suwannee Limestone). Wells tapping these limestones obtain their greatest yield from zones where jointing and subsequent dissolution of the limestone has greatly enhanced the hydraulic conductivity of the rocks. Porosity is the percentage of pore space in the limestone. In general, the porosity decreases with depth, owing to the fact that groundwater circulation and dissolution, which increases porosity, are greatest nearer the earth's surface. Shallow groundwater contains carbonic acid derived from the solution of carbon dioxide from the atmosphere, and water containing carbonic acid is able to more readily dissolve the limestone. The flow of groundwater through solution openings abrades the limestone, further increasing porosity (Krause, 1979). Groundwater circulation is greatest in the upper zones, particularly near the Withlacoochee River where flow is facilitated by the solution cavities and the sinkholes in the stream bed, thus enhancing further dissolution of the limestone.

WETLAND HYDROLOGY

The Grand Bay and Banks Lake wetland complex consists of seven wetland bays and natural lakes: Banks Lake, Old Field Bay, Moody Bay, Moccasin Bay, Dudley Bay, Rat Bay, and Grand Bay. The wetlands are vertically confined or semi-confined by inorganic clays of low to medium plasticity within the middle part of the Miccosukee Formation of

Quaternary age. A build up of organic detritus on the clay base has enhanced the hydraulic confinement. To some extent, the bays are all hydraulically connected through canals and man-made control structures (figure 4). The various bays and lakes are laterally separated by more than 5.7 miles of earthen sills that were constructed by Moody AFB to facilitate emergency access within the wetlands in the event of an aircraft accident, thus, they are locally referred to as "crash trails". Control structures are installed at selected locations within the sills to facilitate and regulate the overland flow of water from bay to bay. Banks Lake is in the north-northeastern part of the study area. It is bordered by Georgia Highway 122, which crosses along the northern edge of the lake. Banks Lake receives overland inflow from Darsey Creek and Copeland Creek on the eastern side of the lake, following periods of heavy rainfall. Banks Lake primarily drains to the north-northeast into Mill Creek. There is a single control structure at Georgia Highway 122 that limits the flow of Banks Lake into Mill Creek.

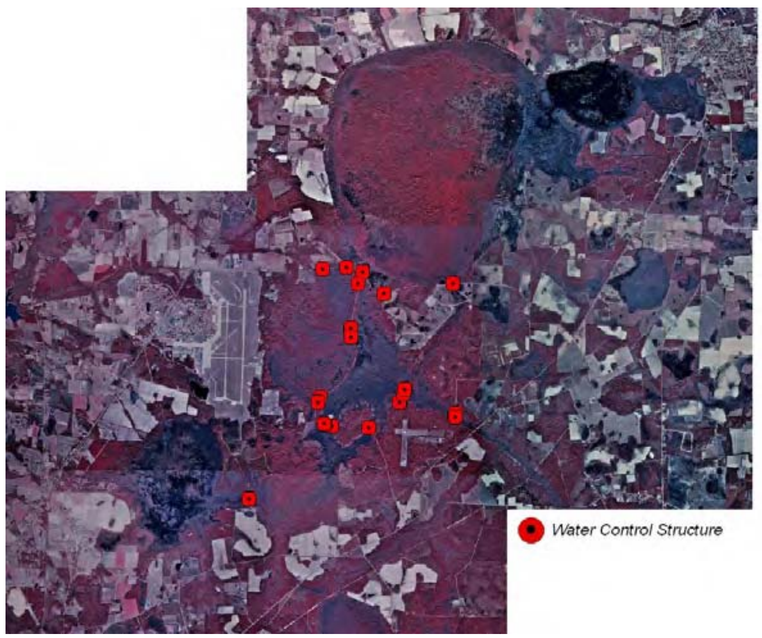


Figure 4.—Locations of water control structures and sills.

Table 1.—Wetland hydrologic characteristics.

Name	Size[1] (acres)	Size[2] (acres)	Elevation Normal Pool[3] (feet ASL)	Flow Capacity Orifices Open[3] (ft^3/sec)
Grand Bay	1,353	1,937	192.2	189
Dudley Bay	250	--	186.8	265
Moody Bay	1,051	--	186.6	449
Rat Bay	840	--	186.6	362
Moccasin Bay	210	--	186.5	460
Old Field Bay	2,000	7,475	191.0	394
Banks Lake	--	1,255	191.0	--

[1]Wetland size from documents provided by Georgia DNR
[2]Wetland size from ArcView Geographic Information System map delineation
[3]Pool elevations and flow capacity from Georgia DNR

The primary inflow to the Grand Bay wetland is through a series of natural and enhanced canals that connect the wetland with the topographic high areas near Bemiss in the southwestern part of the study area. With the exception of Banks Lake and a portion of Old Field Bay, the bays are drained to the southeast through Grand Bay Creek. Old Field Bay is reported to drain both to the north-northeast and to the south into Moody Bay. The bays may also receive a portion of their recharge water from adjacent shallow groundwater sources.

Water-Level Fluctuations

The hydroperiod of a wetland is the seasonal pattern of the water level and is like the hydrologic signature of the various wetland types found in the study area. Essentially, the hydroperiod is an integration of all inflows and outflows of water (Mitsch and Gosselink, 1993). Water levels in the study area wetlands are primarily controlled by the balance between precipitation and evapotranspiration, and anthropogenic manipulation of the control structures. Water-level monitors were installed in the study area at five sites: Grand Bay, Rat Bay, Old Field Bay (Shiner Pond), Moody Bay, and Banks Lake in an effort to measure the hydroperiod as well as to evaluate the fluctuation of the wetland water level in response to inflows and outflows, and control structure manipulation (figures 1 and 4). Data collection began during late spring 2006. The mild drought condition that developed in the study area during late winter 2006 persisted into the summer and resulted in an abbreviated hydroperiod at four of the monitoring sites. Grand Bay, Rat Bay, Old Field Bay (Shiner Pond), and Moody Bay progressively dried and, all but Grand Bay contained no measurable water by early summer. Water levels in Banks Lake were less affected by the drought.

Rat Bay

Water-level monitoring began at the Rat Bay station on April 26, 2006, at which time the bay contained only a small amount of stored water. In addition, there was no flow through the control structure when the station was activated. The pooled water in the bay continued to diminish as a result of evapotranspiration, and by June 18, the bay was dry (figure 5). A rain event on June 14 produced about 2.9 inches of rain in a very short period of time which resulted in a water-level rise of about 0.6 ft. However, short-term periods of intense rainfall during July and August did not result in recharge to Rat Bay. The bay remained dry from June 18, through the remainder of the monitoring period.

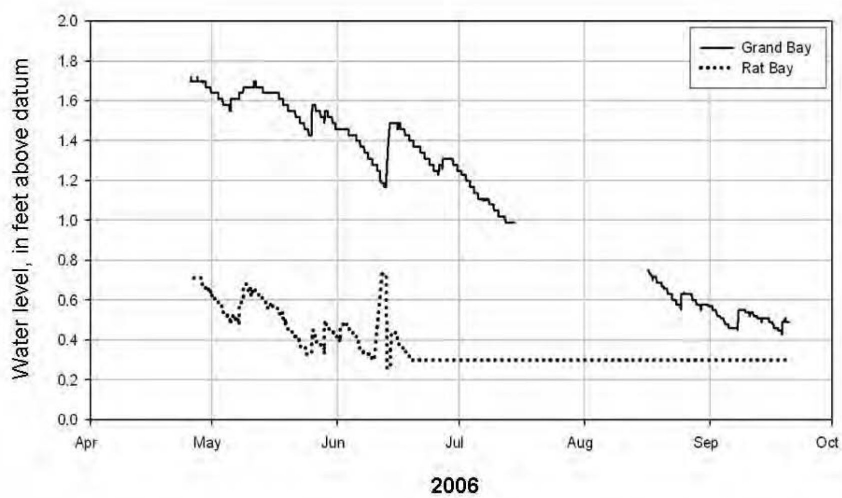


Figure 5.—Water level fluctuations in Rat Bay and Grand Bay.

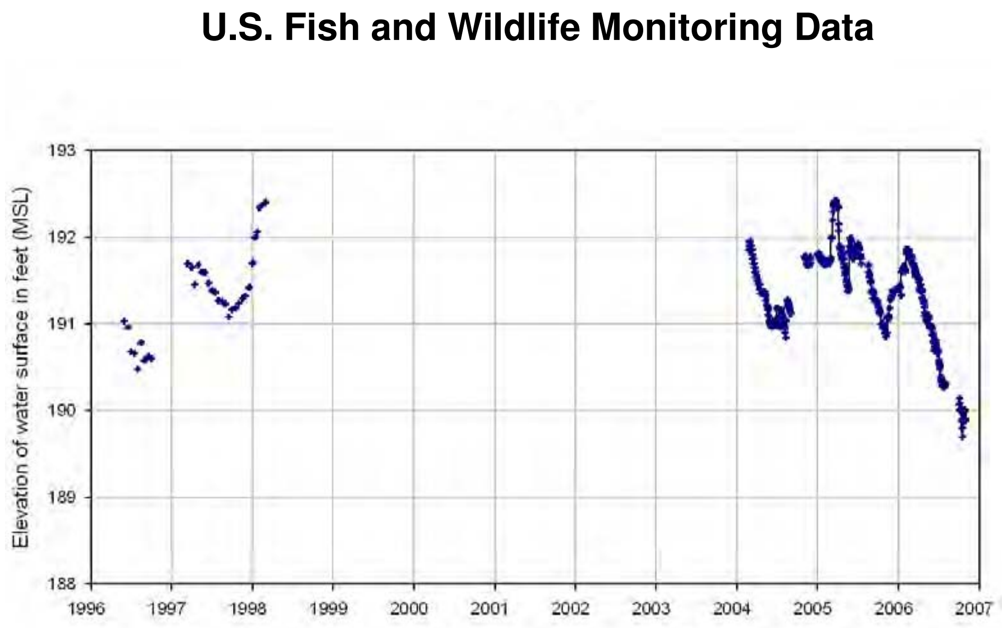
Grand Bay

Grand Bay appears to be topographically deeper than the other bays and as a result maintained stored water through the monitoring period of April 25-September 22, 2006. During the monitoring period the water level in Grand Bay declined about 1.2 ft primarily in response to evapotranspiration loss (figure 5). Boards were maintained in the control structures, thus limiting the amount of outflow leakage through the control structures.

Banks Lake

Banks Lake is the deepest of the wetland lakes in the study area. The water level in Banks Lake declined about 1.0-1.5 ft below the normal level in response to the 2006 drought conditions (Sara Aicher, U.S. Fish and Wildlife Service, oral commune., 2006). Historic water-level data provided by the U.S. Fish and Wildlife Service indicated that

the present level of Banks Lake may be the lowest on record, however, data were not provided for the period that includes the regional drought of 1999-2002 (figure 6). During a normal rainfall year, such as 2005, the lake fluctuated from a low of 190.8 ft above sea level to a high of about 192.4 ft; a seasonal fluctuation of only 1.6 ft. The new monitoring station was installed at Banks Lake during August 2006. During the relatively short monitoring period of August 17, through September 22, the water level increased about 0.4 ft in response to moderate local rainfall that occurred in late August (figures 6).



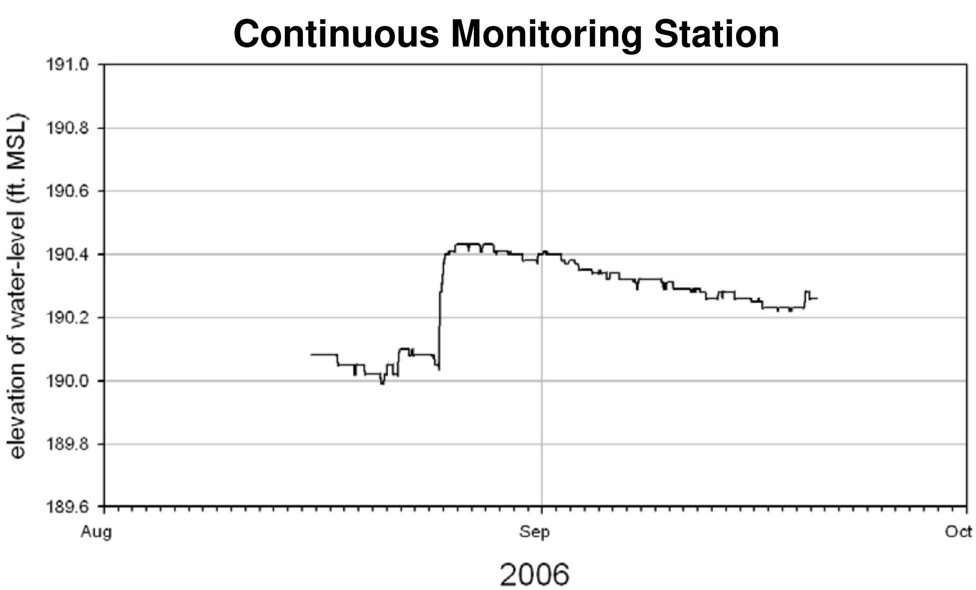


Figure 6.—Water-level fluctuations in Banks Lake.

Wetland Recharge and Groundwater Interaction

The Grand Bay and Banks Lake wetland system is recharged primarily by precipitation falling within the catchment basin. The wetland catchment is defined by the crest of the topographic high that encompasses the basin much like a stream basin or watershed is defined. Rain that falls within the wetland basin contributes to the volume of water stored in the wetland. The components of a hydrologic budget for the wetland recharge include: rainfall, overland runoff, infiltration, evaporation and plant transpiration (evapotranspiration), and shallow groundwater interaction which can add, or remove water from the budget. A portion of the rainfall that infiltrates into the surficial soils is retained in the soil pores and the remainder either leaks deeper into the soil profile, or moves laterally to points of discharge at lower elevations at the wetland.

Recharge by precipitation to the Grand Bay and Banks Lake system occurs mainly during the period December through March when rainfall is typically heavy and evapotranspiration is low (figure 2). Although rainfall can be heavy during July and August, summer storms generally are of short duration and a large part of the water is lost to evapotranspiration and soil-moisture replenishment. In years when tropical weather systems move through the study area heavy rainfall can result in significant recharge to all hydrologic systems including the Grand Bay and Banks Lake wetlands.

Groundwater hydrology may be a significant factor in understanding timing of flows in area streams, water storage in some wetlands and, thus, the hydroperiod. In areas proximate to the wetlands, a portion of the rain water may be temporarily retained in the surficial soil horizon because of the underlying less permeable clayey soil. Where the vertically confined groundwater has a higher hydraulic head than the water surface in the wetland, lateral leakage may occur into the wetland through seeps along the lithologic interface between the more permeable surficial soils and the less permeable clayey soils that vertically confine the wetland. The hydraulic relationship of the shallow groundwater and wetland hydrologic systems varies seasonally as a function of rainfall and evapotranspiration status, soil saturation status, and hydraulic heads in the vertically confined groundwater and wetland. Wetland water may originate from storm-generated runoff traveling through surficial soils, and result as local flow from the saturated surficial soils. It is highly likely that the Grand Bay wetland is recharged partly from the shallow movement of groundwater within the surficial soils. Water data collected at the Grand Bay monitoring station indicated that this bay sustained ponding during the short-term 2006 drought when the other wetlands in the system dried. During most years, the groundwater storage source proximate to the Grand Bay wetland would increase the hydroperiod.

Studies by McConnell and Hacke (1993) speculated that the circular shaped wetland areas called bays in the northern part of their study area (Grand Bay and Banks Lake area) may be a source of recharge to the unnamed aquifer of Pliocene age (Miccosukee Formation) when water levels decline in the aquifer. They suggested that as the water levels in the aquifer decline, the altitude of the water surface in the bays is higher than the water level in the unnamed aquifer; thus, creating a potential for recharge from the bays into the aquifer. Shaw Environmental, Inc identified and described the unnamed aquifer

of Pliocene age (Miccosukee Formation) that is present in the study area. Beneath Moody AFB the aquifer was identified at an elevation of about 185 to 141 ft ASL (Shaw Environmental, Inc., 2005). The base of the confining clay and top of the uppermost water-bearing zone occurs at an elevation of about 185 ft ASL. The surface elevation of Moody Bay, which is directly adjacent to the Moody AFB where numerous test borings have been made (Shaw Environmental, Inc., 2005), is about 186.5 ft ASL. Thus, it is likely that there is very little vertical hydraulic confinement separating the upper water-bearing zone of the unnamed surficial aquifer and Moody Bay wetland. Water-table maps constructed by Shaw Environmental, Inc., indicate that in the general vicinity of Shiner Pond, the projected elevation of water within the unnamed Pliocene aquifer is about 195 to 206 ft ASL. The average water surface elevation of Shiner Pond is about 191 ft ASL. Thus, the hydraulic gradient is reversed from that speculated by McConnell and Hacke (1993) and there exists a hydraulic potential for water to leak from the unnamed aquifer vertically upward into Shiner Pond. Seasonally, parts of the wetlands, primarily Shiner Pond and Banks Lake, may be discharge features of the underlying aquifer. However, the transfer of water between the two hydrologic systems cannot be verified without site-specific hydrogeologic testing. The hydraulic head in the unnamed aquifer is also somewhat higher in the western part of Moody Bay. A comparison of the elevation of the base of Moody Bay and a projection of the elevation of the base of the confining clay suggests that there may be only a 1.5-ft thickness of confining clay underlying that portion of Moody Bay. Hydrogeologic testing has not been conducted in the vicinity of Banks Lake, thus, a comparison of hydraulic heads cannot be made, nor evaluations of the presence of absence of a vertical confining layer.

Flow

Contained within the Grand Bay and Banks Lake system are numerous wetlands and ponds. Understanding the hydrologic function of the wetland complex will require an evaluation of the hydrologic paths and interconnections among the streams, wetlands, and surficial aquifers (where present). Defining hydrologic flow paths and hydrologic linkages can be difficult in the study area because of the low topographic relief and the more than 5.7 miles of constructed hydrologic dikes.

Flow within the bays and between the bays is driven by gravity; water in the bays flows from points of higher elevation to points of lower elevation. The control structures installed in the sills can be manually manipulated to temporarily prevent water from flowing from one bay into another; however, the vertical height of the sill and the size and depth of each bay limit the volume of water that can be stored in the up-gradient bay. The sill height data are not presently available and probably have changed over time as a result of erosion and settling that has occurred since construction. In addition, each sill, with the exception of Moody Bay, has a constructed emergency spillway to prevent destruction of the sill in the event of a catastrophic rainfall event. The elevation of the spillway would be the limiting factor in the depth and volume of water that could be stored in the wetland.

Water that is not lost to evapotranspiration eventually flows out of the wetland complex through Grand Bay Creek to the east-southeast. Grand Bay and Old Field Bay have the

highest elevations among the six bays, 192.2 and 191.0 ft ASL, respectively. The elevation of Banks Lake is the same as Old Field, 191.0 ft ASL. Essentially, Moody Bay, Rat Bay, Dudley Bay, and Moccasin Bay each share the same approximate elevation ranging from 186.5 to 186.8 ft ASL. Based on the reported elevations, Grand Bay and Old Field Bay would contribute flow into the other bays. Grand Bay flows from the west to the east and discharges into Dudley Bay. Old Field Bay flows from a reported elevation high located approximately near the middle of the bay, into Moody Bay and Moccasin Bay. The portion of the flow that enters Moody Bay then discharges into Rat Bay which flows through a poorly defined channel into Moccasin Bay and into Grand Bay Creek.

The time required for flow to move through the wetland complex is highly variable and is dependent on the rate of wetland recharge, which is primarily rainfall driven, and the resulting hydraulic head differentials between the up-gradient and down-gradient bays (discharging bay and receiving bay). Following periods of heavy, sustained rainfall it is possible that flow through the wetlands could be rapid and discharge into Grand Bay Creek could be high.

In order to estimate the potential transit time required for flow to move through the various segments of the Grand Bay and Banks Lake system, a digital model was constructed by a consultant to Georgia DNR (Georgia DNR, written commune., 2006). Because of the large number of assumptions used in the model, the results are useful only as estimates of the performance of the flow system. The wetland flow system was simulated using the equivalent of a 10-year recurrence interval rainfall event: 7.2 inches of rainfall during a 24-hour period. Both peak flow at the outfall control structure of each bay, and the time required for peak flow to develop at the control structure was estimated by the model. Peak flow at Moody Bay was calculated to be 168 ft^3/sec that developed in 39 hours from the onset of the rainfall event. Presumably, the peak flow developed the fastest at the Moody Bay control structures because much of the catchment basin for this bay is within Moody AFB which contains a relatively high percentage of impermeable surfaces such as buildings, roadways, and runways. The model predicted that it would take 65 hours for a peak flow of 650 ft^3/sec to develop at the Moccasin Bay outflow control structure. Moccasin Bay is the last wetland bay in the system before the bay flows discharge into Grand Bay Creek. The calculated peak flow of 650 ft^3/sec would exceed the flow capacity of the control structure at Moccasin Bay by more than 40% and would likely result in the failure of the sill.

Water Chemistry

Because of the hydrologic complexity of wetland systems developed over karst structures like the Grand Bay and Banks Lake system, geochemical approaches can sometimes be used to clarify groundwater contributions to the hydrology and biogeochemistry. Depending on the timing and quantity of groundwater inflow, contributions from the aquifer may dilute certain ions (e.g. rain water derived ions such as chloride) or enhance others (e.g. bicarbonate). In southern Georgia, streams or wetlands not connected to deeper groundwater systems typically have relatively low ionic content, low conductivity, ionic ratios similar to rainfall, neutral to acidic pH, low calcium ion concentrations and

moderate to high dissolved organic carbon concentrations. Water quality in wetlands with direct connection to the deeper aquifers generally have higher pH, higher ionic content, higher conductivity (~10 fold), ionic ratios similar to the groundwater, and low dissolved organic carbon. Chemical characteristics of non-alluvial wetlands with impervious clay layers or those receiving water only from the vadose zone, or surficial soil sources reflect meteoric (atmospheric) and surficial soil processes rather than deeper groundwater processes. If the wetlands are discharge areas for the aquifer, well-defined patterns of variability in the major and minor ions should be present. Land use practices within the wetland catchment basin can further alter the hydrology and chemistry of recharge water entering the wetland, in particular water entering Grand Bay from the developed landscapes near Bemiss.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electrical current. Specific conductance is the reciprocal of specific resistance in ohms and is usually reported in microsiemens per centimeter at 25 degrees Celsius. However, the data sonde used to collect the continuous specific conductance data during this project logged the data in units of millisiemens per centimeter at 25 degrees Celsius (mS/cm), thus, to convert the values used in this report to microsiemens, simply multiply the values by 1,000. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water.

A data sonde was used to collect continuous specific conductance data in Grand Bay, Banks Lake, Grand Bay Creek, and Shiner Pond (Old Field Bay). Grand Bay Creek had the highest specific conductance with a median concentration of 0.080 mS/cm (figure 7). The median specific conductance of water in Shiner Pond was 0.074 mS/cm, which is significantly higher than observed in Banks Lake and Grand Bay, 0.032 and 0.025 mS/cm, respectively.

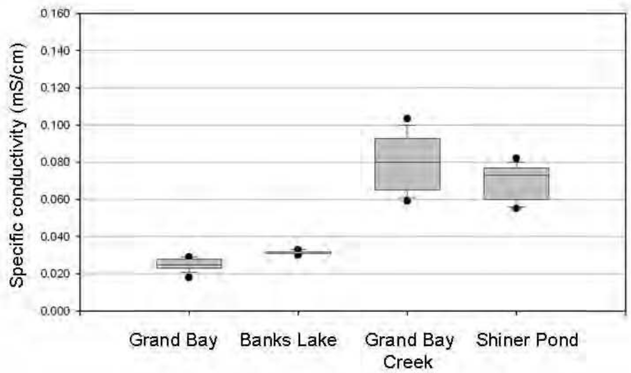


Figure 7.—Specific conductance values taken from water quality monitors.

pH

The pH of water is a measure of the concentration of hydrogen ions. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Water with a pH of less that 7 is acidic, and water with a pH greater than 7 is basic. The pH of natural waters depends on the relative concentrations of carbonate ions, hydrogen carbonate ions, and dissolved carbon dioxide. Rain water in southern Georgia is usually slightly acidic (pH = 5.7) due to the reaction of water and dissolved carbon dioxide from the atmosphere that the rain has fallen through. Through this process a weak carbonic acid is formed. The carbonic acid is largely responsible for the breakdown of rocks to soil during chemical weathering. The leaching of the weakly acidic recharge water through the rocks of the Upper Floridan aquifer is responsible for the formation of limestone caverns and development of the secondary permeability of the Upper Floridan aquifer. The lower the pH, the more acidic the water, and the more minerals it can dissolve. Although carbonic acid is a weak acid, it is very effective over geologic time.

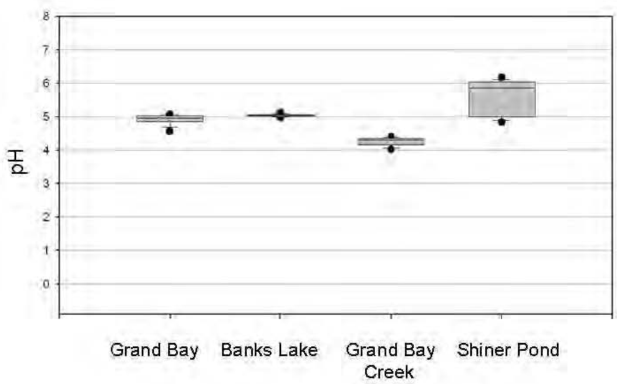


Figure 8.—pH values taken from water quality monitors.

The pH of natural water is controlled, in large part, by its environment. Groundwater in the Upper Floridan aquifer in the study area is usually slightly alkaline (pH = 7.5-8.0) due to the reaction of the weakly acidic water with dissolved carbonate ions from the limestone rocks that the water has passed over and through. Water in streams, wetland ponds, and wetlands that typically dry most years can be acidic or alkaline depending on whether it is precipitation dominated, rock dominated or evaporation dominated. Photosynthesis uses up dissolved carbon dioxide, which acts like carbonic acid in water, and reduces the acidity of the water. However, respiration of organic matter produces carbon dioxide, which dissolves in water as carbonic acid, thereby lowering the pH (Michaud, 1991). In general, wetlands are typically shallow and do not stratify and, thus, lack the chemical complexity of deep-water lakes. But, because they are shallow they do not have the buffering capacity of a deep-water lake and the pH can change rapidly in response to natural or anthropogenic factors (Michaud, 1991). In fact, during the growing season, the effect of photosynthesis can observed as diurnal cycling in the pH in Grand Bay, Old Field Bay (Shiner Pond), and Banks Lake. Continuous pH data collected by the water quality data loggers shows a daily fluctuation in the pH of about 0.2-0.3 pH units, which is most noticeable in Banks Lake.

Aquatic life is also affected to an extent by the pH of the ambient water. Many biological processes, such as reproduction, cannot function in acidic waters. A pH in the range of 4.0-5.0 can affect the reproduction of fish, and when the pH drops below 4.0 the water can become unsuitable for most fish to live. According to many studies, waters that become overly acidic (pH less than 4.0) can result in the death of adult fish. The median observed pH of Grand Bay and Banks Lake was about 5.0 during the monitoring period (figure 8). As Grand Bay began to dry during late July and August, the water became slightly more acidic and the pH declined to about 4.6. The pH of Banks Lake remained relatively constant throughout the monitoring period. The water in Grand Bay Creek,

which drains the major part of the wetland complex, was more acidic than the waters in the wetlands. During the monitoring period the median pH was about 4.3 and the pH ranged from 4.0-4.5, which is in the range where the fish population could be affected by the acidity of the water. The median pH of waters in Old Field Bay (Shiner Pond) was 5.8, which was significantly higher than the pH in Banks Lake, Grand Bay, or Grand Bay Creek. In addition, the pH in Shiner Pond ranged from 4.8-6.2 which was a much larger range than in the other monitored sites.

Dissolved Oxygen

Dissolved oxygen (DO) is a basic requirement for a healthy aquatic ecosystem. Most fish and beneficial aquatic insects "breathe" oxygen dissolved in the water column. Some fish and aquatic organisms (such as carp and sludge worms) are adapted to low oxygen conditions, but most desirable fish species suffer if dissolved oxygen concentrations fall below 3 to 4 milligrams per liter (mg/L) and larval and juvenile fish are more sensitive and require even higher concentrations of DO (Caduto, 1990). Many fish and other aquatic organisms can recover from short periods of low DO availability. Prolonged episodes of depressed DO concentrations of 2 mg/L or less can result in eutrophication and the loss of many aquatic species.

Oxygen concentrations in the water column fluctuate under natural conditions. Decaying organic matter can reduce, and in some cases deplete the oxygen supply required by aquatic organisms. Depleted oxygen levels, especially in bottom of the wetlands where dead organic matter tends to accumulate, can reduce the quality of fish habitat. The water temperature also influences the amount of oxygen dissolved in water because warm water cannot hold as much oxygen as cold water. DO concentrations are lower in warmer water and prolonged hot weather will depress oxygen concentrations. The DO concentration within a wetland can experience large daily fluctuations. Aquatic plants and algae produce oxygen as a by-product of photosynthesis by day. But at night, they consume oxygen through respiration. Productive water bodies, those with large populations of aquatic plants or algae, are likely to experience the greatest DO fluctuations. In such water bodies, the DO concentration is usually lowest just before sunrise, and highest in late afternoon (Caduto 1990).

DO was monitored in Grand Bay, Banks Lake, Grand Bay Creek, and Old Field Bay (Shiner Pond) during this study. The median concentration of DO was about 1.2 mg/L in Grand Bay and Shiner Pond (figure 9) and 6.3 mg/L in Banks Lake. The DO concentration ranged from almost zero to 2.0 mg/L in Grand Bay Creek. Based on the observed data, the DO concentration in Grand Bay Creek was not sufficient to support aquatic life. The DO concentration in Grand Bay ranged from near zero to greater than 9.0 mg/L. Daily fluctuations of as much as 6.0 mg/L were observed during late July and August.

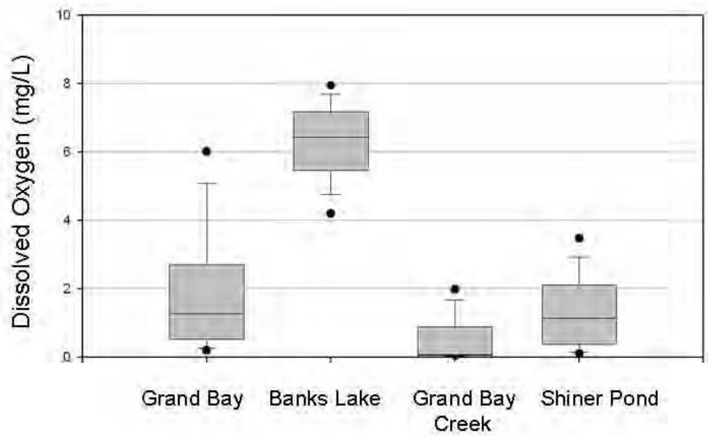


Figure 9.—Dissolved oxygen concentrations taken from water quality monitors.

Temperature
Biological and chemical processes in wetlands are dependent on water temperature. Temperature influences the amount of dissolved gases and, thus, the DO concentrations are lower in warmer water. Also, higher temperatures would encourage the growth of algal blooms, which consume oxygen during decomposition. Water temperature is also important because it influences chemical reaction rates in the wetland waters and metabolic rates in fish (personal commune., Dr. Steve Golladay, 2006).

Many factors influence wetland and stream water temperature, including seasonal air temperature, water depth, groundwater inflow, mixing as water flows through the wetlands, and the amount of sunlight and shade. Water temperature plays an important role in aquatic ecosystems (Caduto 1990).

The water temperature of Grand Bay, Banks Lake and Old Field Bay (Shiner Pond) ranged from about 24 to 32 degrees Celsius (^{o}C); however, the temperature of Grand Bay Creek was much cooler and ranged from about 22 to 26 ^{o}C (figure 10). Banks Lake had the highest median temperature of 30.4 ^{o}C , while Grand Bay Creek had the lowest median temperature of 24 ^{o}C . The temperature record showed a clear diurnal fluctuation in response to the daytime heating effect of the sun, and the thermal cooling during the night. During late August the daily temperature range increased in response to the drying of the wetlands. It is likely that the observed temperature ranges would be significantly different during a period of time of normal, or above normal rainfall when there was continual water movement through the wetlands.

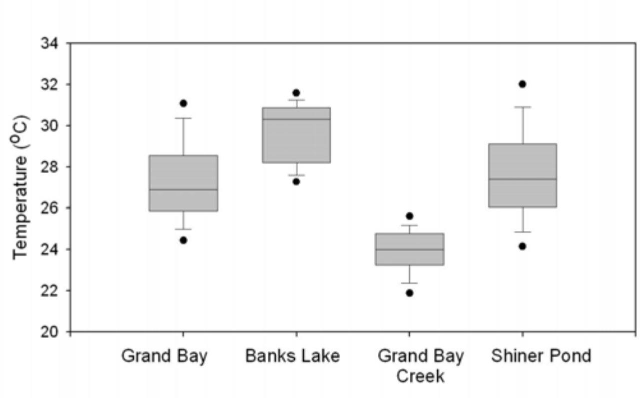


Figure 10.—Water temperature fluctuations taken from water quality monitors.

DISCUSSION and CONCLUSIONS

Expansive palustrine wetlands require frequent fire to prevent the invasion and growth of undesirable, dense, understory vegetation that reduces their ecologic function. In addition, the understory encourages the nesting of bird populations that create a hazard to air craft. The northwestern part of the wetland is adjacent to Moody AFB and underlies their runway approach, and birds flying in the wetland area could damage low flying aircraft. Typically, wetland fires burn for extended periods of time and produce significant dense smoke as a result of the peat layer that develops from organic decay of vegetation. Dense smoke significantly limits the ability of aircraft to utilize the Moody AFB facility and, thus, could jeopardize the execution of their defense and training missions. Prolonged smoke may also create hazardous driving conditions on area roadways, as well as health problems for area residents. Thus, the challenge is the use of prescribed fire to maintain the ecologic function of the wetlands and limit the growth of undesired understory is the vicinity of the regulated Moody AFB facility, and provide a mechanism to rapidly extinguish the fire once the primary burn is completed. A major purpose of this investigation was to evaluate the interbay flow system and determine if the existing control structures could be manipulated during normal hydrologic conditions to facilitate the use of prescribed fire as a wetland management tool.

Site-specific hydrogeologic exploration conducted by Shaw Environmental, Inc., has shown that there is likely very little vertical confinement separating the unnamed aquifer of Pliocene age (Miccosukee Formation) and parts of Moody Bay, Shiner Pond, and potentially Banks Lake. The water quality monitoring conducted during this study also indicates that the chemical signature of water in Shiner Pond and Banks Lake is somewhat different from that observed at the other monitored sites. Because of the drought conditions, a representative water sample from Moody Bay was not available, thus a chemical signature could not be established. However, based on the available data it is likely that the water in Shiner Pond and Banks Lake, during the monitored period, represented a composite of precipitation derived water and groundwater. Unless there is some form of direct connection, such as a sinkhole, it is unlikely that the groundwater interaction with the wetlands would affect the hydrology during the short time period when fire would be in the wetland.

Flow within the bays and between the bays is driven by gravity; water in the bays flows from points of higher elevation to points of lower elevation. The control structures installed in the sills can be manually manipulated to prevent water from flowing from one bay into another; however, the vertical height of the sill and the size and depth of each bay limit the volume of water that can be stored in the up-gradient bay. The sill height data are not presently available and probably have changed over time as a result of erosion and settling that has occurred since construction. In addition, each sill, with the exception of Moody Bay, has a constructed emergency spillway to prevent destruction of the sill in the event of a catastrophic rainfall event. The elevation of the spillway would be the limiting factor in the depth and volume of water that could be stored in the wetland. Grand Bay and Old Field Bay have the highest elevations among the six bays, 192.2 and 191.0 ft ASL, respectively. The elevation of Banks Lake is the same as Old Field, 191.0 ft ASL. Essentially, Moody Bay, Rat Bay, Dudley Bay, and Moccasin Bay each share the same approximate elevation ranging from 186.5 to 186.8 ft ASL. Old Field Bay and Banks Lake are hydraulically connected and are not separated by a sill, thus, it is presumed that Old Field Bay and Banks Lake share the same body of water but have somewhat independent drainage characteristics. The northeastern portion of Old Field Bay reportedly drains into Banks Lake, while the remainder of the bay drains into Moody Bay and Moccasin Bay through control structures. Based on the reported elevations, Grand Bay and Old Field Bay would contribute flow into the other bays while Banks Lake would only drain to the north. Grand Bay flows from the west to the east and discharges into Dudley Bay. The portion of the flow that enters Moody Bay then discharges into Rat Bay which flows through a poorly defined channel into Moccasin Bay and into Grand Bay Creek.

The time required for flow to move through the wetland complex is highly variable and is dependent on the rate of wetland recharge, which is primarily rainfall driven, the resulting hydraulic head differentials between discharging bay and the receiving bay, and the flow capacity of the orifice opening of the control structure. According to the model produced for Georgia DNR, periods of heavy, sustained rainfall can create significant flow through the wetlands and discharge into Grand Bay Creek could be high.

In order to estimate the effectiveness of the manipulation of the control structures to facilitate the use of controlled fire as a wetland management tool, it is necessary to calculate the storage capacity of the individual wetlands and the time required to transport the water from the area it is stored to the burning wetland. It is assumed that the water transfer would be gravity driven, thus, Grand Bay and Old Field/Banks Lake would function as the primary water storage areas.

The storage capacity of Grand Bay was determined using the bay size measured using ArcView GIS from a 1999 digital orthographic quadrangle map. Grand Bay was measured to occupy an area of 1,937 acres, which is substantially larger than reported by Georgia DNR (1,353 acres). The volume of Grand Bay at normal pool was calculated to be about 168,750,000 ft^3 assuming an average bay depth of 2.0 ft. The bay volume was also calculated to be about 253, 127,000 ft^3 assuming that the control structures could be closed and the average bay depth increased to 3.0 ft. Thus, the additional stored volume

would be about 84,377,000 ft^3. The reported maximum flow rate of the control structures on Grand Bay is 189 ft^3/sec. Based on this maximum flow rate, it would take approximately 124 hours, or 5.2 days to move the stored volume of water, above normal pool, from Grand Bay into Dudley Bay.

The storage capacity of Old Field Bay and Banks Lake were also determined using ArcView GIS. Old Field Bay was measured to be 7,475 acres, and Banks Lake was measured to be 1,255 acres. Georgia DNR reported the size of Old Field Bay to be 2,000 acres, and TNC reported Banks Lake to be 4,000 acres of wetlands including 1,000 acres of open water (www.sherpaguides.com/georgia/wildlife). It was assumed that the Banks Lake control structure at its discharge point at Georgia highway 122 into Mill Creek could be closed and Banks Lake and Old Field Bay would function as one hydrologic unit at higher water-surface elevations. Using our GIS measured areas, the combined normal pool storage would be about 707,100,000 ft^3 and the added storage volume would be about 380,300,000 ft^3 if the assumed water depth was increased by 1 foot. The maximum flow rate of the control structures was reported by Georgia DNR to be 394 ft^3/sec. A control structure map provided by Moody AFB shows that Old Field Bay drains into both Moody Bay and Rat Bay; four control structures on Moody Bay and one control structure on Rat Bay. The information provided by Georgia DNR does not identify maximum flows through each control structure. Thus, if we assume that the maximum rate of flow through the five control structures is 394 ft^3/sec, then it would take approximately 268 hours, or 11.2 days to drain the excess stored water from the Old Field Bay and Banks Lake areas into the receiving catchments.

Although there is potential to store water and transfer the stored water from Grand Bay and Old Field Bay (including Banks Lake) into Moody Bay, Dudley Bay, Rat Bay, and Moccasin Bay there are several reasons why this may not be a feasible management tool to consider for fire suppression:

1. The volume of stored water would certainly be sufficient in the larger, up-gradient bays to extinguish a prescribed fire in any one of the smaller bays. However, because of the limited flow-thru capacity of the control structures it would take several days of drainage of stored water before a fire could be completely extinguished.
2. If the control structures were closed at Grand Bay and Old Field to allow water to store, then there would be no driving force to push water through the smaller wetlands. Essentially, the topographic elevation of Moody Bay, Dudley Bay, Rat Bay, and Moccasin Bay is the same and there would be insufficient hydraulic head differential to drain the bays under the force of gravity. If the higher elevation water sources were eliminated by closing the control structures it is likely that the water would become stagnate in the smaller bays. More so, if the wetland system was saturated, as would be expected if flow was entering Grand Bay and Old Field Bay at a rate adequate to store water, then the smaller wetlands would likely remain saturated as well and not dry sufficiently to be burned.
3. The storing of water in Grand Bay, Old Field Bay, and Banks Lake at an above normal pool elevation could result in the flooding of adjacent properties. A determination of maximum allowable storage increase should be calculated prior

to closing the control structures. If precipitation occurs during the period, the inflow to the closed wetland areas should be monitored to ensure that the control structure closure does not cause flooding and property damage.

Although habitat destruction is not a threat to Grand Bay and Banks Lake wetland system, impacts from habitat degradation seem to be currently more impending. Degradation is occurring primarily as the direct result of the lack of frequent fire in the wetland which has eliminated key natural ecological processes and allowed unconstrained growth of understory. There is also degradation occurring due to fragmentation from roads and utility corridors, the results of population growth, changes in water quality, and the spread of non-native species. The biological diversity and complexity of natural community assemblages represented at Grand Bay and Banks Lake are environmentally significant, but the future of these resources is not secure. Not unlike many of North America's finest natural areas, Grand Bay is besieged by a variety of environmental stresses. Alteration and degradation of sensitive habitats can be subtle, often occurring over long periods of time. The primary stresses impacting the natural communities at Grand Bay and Banks Lake include: habitat loss, fire suppression, exotic species, and alteration of hydrology, and potential for water quality degradation. There remains an urgent need for additional data including a biological inventory; water quality baseline information; in particular in those areas of Grand Bay and Banks Lake where overland runoff and septic systems can degrade the water quality; and the hydrologic flow regimes need more definition during normal rainfall and flow conditions.

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Grand Bay-Banks Lake Strategic Plan
Fire Component

Fire Management Plan

Kevin Hiers, Matt Greene and Alison McGee

INTRODUCTION

Fire is a key ecological process that has a role in shaping most ecological systems in the coastal plain. The Grand Bay-Banks Lake region is in the highest fire frequency band of the southern US, where the original fire frequency, primarily based on lightning in the coastal plain, with some supplemental effect by Native American burning, averaged as high as 1-3 years (Appendix A). Prescribed fire is a necessary management tool to maintain ecosystems in today's fragmented landscape. In the absence of adequate prescribed fire, the Carolina bays in the GBBL are changing in character, shifting from open, emergent marsh vegetation to scrub-shrub vegetation (Appendix B). This plan outlines considerations and approaches that may be used in the GBBL ecosystem to increase the frequency of fire in certain areas to meet management objectives.

Resources at Risk in the GBBL Landscape

There are important factors that must be considered when discussing fire on the landscape. Fire must be carefully planned and judiciously applied at Grand Bay-Banks Lake. Some areas and some time periods are not appropriate for prescribed fire due to high risk - fire should be avoided in these areas and at these times. Factors include

1) *Public Safety Concerns*

The growth of Lowndes County around the Moody AFB area has been dramatic and unplanned. This growth has led to increasing wildland urban interface (WUI) adjacent to unnatural and hazardous fuel loads in the Grand Bay Banks Lake region. The need to control fire and to reduce fuel loads in both upland and wetland ecosystems is critical for public safety

2) *Military Mission*

Preservation of the military mission is paramount to the conservation effort in the GBBL area. The current mission at Moody AFB centers around pilot training and requires very specific rules governing flight operations. Visual flight rules (VFR) prevent pilot trainees from when visibility is reduces below a certain level. Wildland fire management, both prescribed fire and suppression, must be considered in this context. With the Base Realignment and Closure process underway, Moody AFB will likely see a return to A-10 anti-armor mission activities which are much more flexible to smoke impacts. Critical reevaluation of smoke management must be done throughout this transition period to ensure good fire management.

3) Rare Species and Natural Communities

There are a number of fire dependent ecological communities that require a proper managed fire regime. These communities harbor a number of rare threatened or endangered species. While many of these areas require frequent fire, some are not fire

dependent (e.g., Dudley's Hammock) and care must be taken in these areas. Using an adaptive approach to use infrequent, ecosystem-altering fires can provide the management necessary to maintain these natural communities and rare species.

SMOKE MANAGEMENT PLAN

Smoke management is perhaps the most difficult component to fire management in the GBBL ecosystem. The proximity to Moody AFB center of operations, US Highways 221 and 84, and suburban sprawl make smoke management the primary concern for prescribed fire in the GBBL region. Smoke management issues will be unique to individual burn units and weather conditions on the day of the burn. In general, the following smoke management guidelines should be considered at the landscape scale, but specific guidelines must be developed for each burn unit.

a. Smoke sensitive areas within 10 miles of GBBL include hospitals, nursing homes, the Moody AFB main runway, the municipalities of Lakeland, Valdosta, Ray City, Naylor, and Bemiss. Additional smoke sensitive areas include subdivisions to the east and west of the project area (Figure 1).

b. Down-drainage road crossings are a major smoke management hazard associated with prescribed burning in the GBBL area (Figure 1). Given the accumulation of organic matter in these fire-excluded and hydrologically modified wetlands there is substantial risk for smoldering phase combustion long after any prescribed fire near or within wetland features. US 221 (1.5 miles) and US 84 (10 miles) are at immediate and moderate risk of down-drainage smoke drift, respectively. With light winds and the subtle gradient, smoke drift will be slow and dense resulting in loss of visibility on US 221 at Grand Bay Creek. Burns should be conducted with LVORI values of 7 or below predicted for the nighttime dispersion. GFC and DOT should be notified of this potential when burning and major wetland features or large landscape blocks. Though uphill, smoke fog hazard is also possible on the Moody Main runway during extremely poor nighttime dispersion or high LVORI values given the low relief of the GBBL terrain. Consultation with military operations personnel will be critical when burning major wetland features with smoldering potential.

c. Education of adjacent landowners, businesses, and emergency management personnel is a critical component to successful smoke management. Presentation of fire management plans and objectives in the GBBL area should be developed for distribution among the partner organizations. These presentations should be targeted to the Chambers of Commerce, Emergency Management Coordinators for each county and municipality with 10 miles, civics clubs including Kiwanis and Rotary, Military officials, hospitals, nursing homes, and homeowner associations within the Bemiss, Moody AFB, and Lakeland communities.

WILDFIRE MANAGEMENT PLAN

Suppression actions taken are dependent on the area, fuels, fire behavior, resources at risk, weather, and the suppression resources on hand. Because Moody AFB supports an

active munitions test and training program as well as unique ecological resources in the GBBL area, there are limits to wildland fire suppression activities. Moody AFB, GA DNR, and GFC personnel responsible for deciding suppression actions in the areas listed below will be the, Chief Environmental Officer, the DNR Regional Biologist and the County Ranger.

- Active Military Missions – If active missions are ongoing, suppression activities may be restricted. Decisions regarding suppression on active test areas requires coordination with Range Control and assessment of the current and potential fire situation. Designated Moody AFB Fire personnel will make these decisions. Depending on fuel, mission, and other fire activity, suppression may take any form, from full, direct line construction to a block and burn containment strategy. At all times the safety of firefighting personnel will be the governing consideration.

- Biologically sensitive areas where plow operations are generally not conducted include wetlands, bays, high quality natural areas (i.e., Dudley's Hammock), and threatened and endangered species habitat. There are multiple reasons for not using plows in these areas. If wildfire conditions are such that plowed lines are deemed necessary in these areas, the regional biologist for GA DRN, Moody Manager, USFWS Refuge Manager, or their designee(s) will approve the use and location of the lines.

Due to these conditions several special treatment areas are identified across the GBBL conservation area, as follows (Figure 2):

- Fire Management Zone 4—(**no plow zones**). Several areas are identified on Figure 2 where plows will not be used for fireline construction except in extreme conditions and with the approval of the Moody Natural Resources Manager, GA DNR Regional Biologist, USFWS Refuge Manager, or their designee. Indirect attack or helitack is the preferred methods of suppression. This prohibition for direct attack with dozers is to prevent ecosystem damage from modification of hydrology, vegetation damage, or potential underground power or communication lines.
- Fire Management Zone 3 (**direct suppression**). This area contains the Moody AFB operations areas, DNR assets, and includes urban interface areas on and adjacent to the management area. Suppression actions in this zone will be the highest priority, and response will be closely coordinated between GFC, base and local fire departments. GFC personnel will direct wildland fire operations with the base and local fire department, providing structural protection and assistance, including logistical support for wildland suppression when possible. Partners include the Moody Fire Department and local structural fire departments.
- Fire Management Zone 2 (**indirect suppression**). These areas are the type-case for suppression actions. In this zone suppression of wildfires will be taken with the primary consideration given to the safety of firefighters and other resources. Consideration will also be given to the visiting public that may be in the area.

Prior to establishment of firelines, the erodibility of the soils, the type of vegetation along the proposed fireline, and the effects of line construction on the hydrology of the area will be taken into consideration. Every effort will be made to prevent construction of unnecessary firelines. If indirect attack is possible it is preferred, but not mandated.

- Fire Management Zone 1 (**fire use**). In addition to all the considerations for FMZ – 2, this zone would be considered for use of unplanned ignitions (UPI) for prescribed fire (fire use). This means that if conditions in the vicinity of an ignition meet those in a preplanned, prioritized, prescribed fire project, the fire could be used as the ignition source and the incident treated as a prescribed fire. Indirect attack is the preferred means of treating these areas when suppression is deemed necessary but not an immediate threat. A risk assessment would accompany the decision to manage/convert an unplanned ignition into a prescribed burn or to consider indirect attack.

  The Risk Assessment should contain information about:

  - Safety risk to firefighters.
  - Fuel conditions.
  - Current and predicted weather.
  - Munitions in use at time of ignition and the likelihood of live rounds in and/or adjacent to the fire.
  - UXO from previous missions.
  - Impacts on current or scheduled test missions.

WILDLAND FIRE USE and UNPLANNED IGNITIONS

Unplanned ignitions from lightning strikes, mission starts, etc., may be used as a management tool (“fire use”) if current and expected conditions fall within the parameters of management prescriptions for the area, provided that adequate personnel and equipment are available to manage the fire as a prescribed burn. The Georgia Forestry Commission, GA DNR, and Moody Natural Resources staff must be informed of the decision to allow an area to burn, ensuring that the fire will not interfere with values at risk, such as missions, other planned activities, study plots, or other concerns in the burn area.

The wetland complex of Carolina Bays and swamp streams are primarily fire dependent ecosystems that have undergone extreme alterations in fire regime over past 50 years and longer. Due to the smoke management threat, fire use and indirect attack may be the only means of effectively managing fire in large portions of the GBBL ecosystem. Each major bay complex should have a specific fire use plan written for it to allow wildland fire use and unplanned ignitions to restore those ecosystems where frequent prescribed fire is logistically or politically unfeasible.

- Moody Bay and Rat Bay: While Moody Bay is one of the top priorities for prescribed fire to eliminate scrub habitat used by bird flock (and increased BASH hazard), currently no fire use is recommended in this wetland due to its proximity to runway, some urban interface, and the potential for this pocosin habitat to burn across contingency lines. Prescribed fire in sequential steps is the best means of managing fuels in this wetland and direct suppression should help to minimize impacts to resources at risk. Rat Bay, just east, down-drainage from Moody Bay is separated by a crash trail. The alteration of hydrology and its position lower in the landscape, will likely limit the opportunities for fire use and unplanned ignitions in Rat Bay; however, it is ideal for fire use if an ignition does occur. This wetland should be burned in advance of Moody Bay to control down wind fire spread. Given the flexibility for smoke management in this area, all fires should be considered for unplanned ignitions and fire use.
- Grand Bay lies at the south end of Moody AFB's Main runway. While periodic drydowns are necessary to help decomposition accelerate the processing of organic matter, fire use in this wetland is not recommended. Rather a wildfire management plan should be established specifically for this block during periods of drydown (See Section IV). This plan should require the establishment of a perimeter fire break buffering all private lands and urban interface to West and Southwest. Prescribed fire is the best means of restoring this wetlands feature, but only through modest and sequential burning will Grand Bay be managed with fire. Suppression and resource protection are a priority for fire management in this wetland feature
- Oldfield Bay is perhaps the best wetland to allow fire use. Its large size, coupled with the rim of fire resistant vegetation surrounding this bay, make fire use within the emergent fringe habitat easy to justify. While it is recommended that Oldfield Bay be used to hold water back for fire suppression in Moody Bay as a contingency for post-prescribed burn smoldering (Section VI), periodic drydown is necessary to maintain the grassy blocks within this wetland. Periodically with natural drydown, if lightning or other ignition sources cause a wildfire, portions of this bay are very suitable for fire use, particularly where emergent fringe vegetation dominates at the southern portion of the bay.

PRESCRIBED FIRE

Prescribed fire plan

Strategic prescribed burning is meant to enhance acres burned through cooperation, co-location of burns, and strategic annual burn blocks within the land scale. Use prescribed fire (Rx fire) to buffer wetlands, ranges, and other fire use habitats to ensure opportunities to let fire burn if possible. The Rx fire goal is to burn all fire-dependent habitat with an appropriate fire return interval, but with large Carolina bay features, there must be a strategy to lay the groundwork for successful prescribed burns.

Strategic burning priorities

- Maintain high quality natural areas identified by longleaf pine and natural slash pine stands on the current vegetation map.
- Buffer the three core natural areas with high fire frequency at all times of year on both public and private lands adjacent to the core natural areas.
- Use strategic annual burning adjacent to Grand Bay and Moody Bay to prepare the bay for helicopter ignitions. These buffer burns should ensure that all WUI considerations are mitigated for, allowing fire use in the wetland complex without the need for direct attack. Oldfield and Grand Bay will be burned in small portions at first to meet modest objectives.
- Burn adjacent private landowners to increase the fire management within the conservation area boundary using the IBT and GFC to burn those lands (voluntarily) at no cost to the landowner.
- Burn the remainder of the upland acreage at the appropriate fire return interval.
- Aerial Ignition Burn Block Primary fire management blocks are large scale blocks designed to utilize aerial ignitions to dramatically increase acres burned and the fire return intervals of priority areas.

Moody Bay

Moody Bay is currently dominated by scrub shrub habitat that needs to be reduced in extent to address BASH hazards from red-wing black birds and other flocking birds that thrive in that habitat. Aerial ignition using the PSD machine has proven inadequate to burn off the shrub cover due to the lack of fuel ladders and fuel continuity. A helitorch is needed to ensure proper fire behavior through the titi and ericaceous fuel bed. Because the helitorch is a large scale burning tool that does not allow the same the control over fire behavior as grid ignition, there are several preliminary steps that must be taken to ensure burn success and control.

Because a westerly component wind will be used to ignite this block (taking smoke away from Moody main runway, Crash Trail 6 will be used at the eastern boundary. Moody Bay flash boards risers must be open for several months allowing continuous drainage into Rat Bay. Rat Bay is also composed of mainly scrub shrub pocosin habitat, and with expected fire behavior of this fuel type ranging from high to extreme, Rat Bay must be burned first to prevent fire runs over Crash Trail dividing the two wetlands. The fire in Rat Bay is meant only to ensure containment during helitorch operations in Moody Bay, and therefore can be patchy. Simply lighting the NW side of the Crash Trail 6 maybe sufficient to secure Moody Bay for helitorch operations. Other pocosin burns can produce flamelength of 60+ feet and rates of spread in excess of 100 chains per hour, and once helitorch operations begin, the fuels downwind of strip fires unit will be difficult or impossible to suppress.

Using seasonal dry down in late spring or fall, the Moody Bay unit will be lit when there is no conflict with mission activity (smoke will obscure the test and training area). While it is unknown whether water from Oldfield bay would be sufficient to extinguish all risk of smoldering fire, nonetheless, water should be held back at the Shiner’s Pond dike to its highest level possible and released into Moody Bay following the burn. The 4.5 foot

difference in reported elevations between Oldfield Bay and Moody Bay should theoretically be sufficient to allow water to aid in suppression (difficulties with this approach are addressed in the Hydrology Plan). This suggestion is only a contingency, and the day chosen to burn should be chosen to minimize the potential for smoldering fire (either immediately after or before a rain event). Burn prescriptions parameters will include no wind > 15 MPH (20 ft WS) and no predicted LAVORI values of >7 in the next 36 hours (to protect against smoke settling down-drainage on Hwy 221 at Grand Bay Creek).

If there is no water holding capacity at Oldfield Bay, but there is a burn window in Moody Bay, the decision to proceed must include direct approval by the base commander with a briefing of the potential consequences of smoldering fire and smoke impacts to the military mission.

Oldfield Bay
Oldfield Bay is largely shrub-scrub and gum swamp successional cover types. Due to its large size and historic modifications to hydrology which have contributed to this forest conversion, Oldfield Bay will primarily be used as water storage in the landscape with two notable exceptions. There are two remnant patches of emergent fringe vegetation including pitcher plants One block is due north of Shiners Pond approximately 300 acres, and the other patch is west of Bank's Lake bordering the DOT mitigation property. Each of the blocks needs ignition soon to preserve this emergent vegetation. Due to the grassy character of these wetlands, drawdown of the water level should expose sufficient grassy fuels that will allow quick effective ignition using a helicopter with a PSD machine. This could be accomplished any time of year without significant risk of escape. Each of these blocks should be considered FMZ 4 and no direct suppression should be taken if an unplanned ignition occurs in or adjacent to these areas. There are no resources at risk near these units, and the surrounding fuels are not pyrogenic making the management of fire in these priority areas a relatively simple matter.

Grand Bay
Grand Bay is one of the most difficult areas to burn in the GBBL complex, but it remains one of the most threatened portions of the areas due to fire exclusion. The complexity of fire management is high since it is owned by both public and private landowners as well as its location at the south end of the main runway. There is a series of steps that must precede any effort to burn significant portions of this wetland. First, a permanent firebreak should be established along the western boundary of this wetland. This strategy is borrowed from the success that Okefenokee NWR has had with the "swamp break" as a contingency line for fire use and prescribed burning. While there is clearly a tradeoff with ecosystem health, this break is necessary to provide separation from the growing WUI to the west of Grand Bay. This break will serve a suppression function in the event of a natural wildfire, but it is also a necessity that must precede prescribed fire operations of any consequence within the wetland. Second, annual fires must be pursued on the partner lands along the upland wetland ecotone. Annual fire will allow managers to take advantage of seasonal droughts to burn wetland vegetation by simplifying holding

concerns in the wetland. Burning uplands will encircle wetlands fuels with previously burned areas that will not carry fire again even late into the growing season.

Multiple fires during the same season can also be used to burn emergent fuels as they are exposed during drydown. Pulling flashboard risers and burning exposed fuels will be an effective, albeit slow, process for safely and methodically burning wetland habitat within Grand Bay.

Ultimately successful fire in this wetland feature must include cooperation within private landowners who own nearly ½ of the Bay. Burn blocks should extend across ownership boundaries to successfully manage fires. Private landowners should be made aware of the opportunities for free burning services via programs like the Interagency Burn Team and USFWS Partner Program.

Other unique considerations for prescribed fire in Grand Bay are the Grand Bay Educational Complex, the board walk, and public access to recreation. Annual fire is already being used in uplands adjacent to the Education Center, and stepwise drawdown and prescribed fire should be sufficient to protect the board walk. Portable pumps and hose lay may be necessary along the boardwalk and observation tower is larger burns are conducted in Grand Bay.

Private land burn priorities in the GBBL landscape
Private landowners play a critical role in the fire management of the GBBL region. They not only own significant portions of wetlands like Grand Bay, but the buffer high quality longleaf forests and other wetland features along the eastern portion of the portfolio site. Cooperation and public acceptance for fire management is a determinant for long-term success. Building strong relationships with landowners that already burn their forests is key, and then leveraging that support to get fire on other landowners who do not burn should be a strategy for increasing prescribed fire across the landscape.

The interagency Burn Team, led by GFC, has money available to burn private lands adjacent to public ownership. This vehicle should be pursued with GFC to approach the landowners to voluntarily participate in the burning program. Producing an education pamphlet that describes cost share programs for prescribed fire would also aid in the goal of increased burning on adjacent private landowners. Particular focus should be on the three major landowners to the NE, SW, and SE of Grand Bay.

CONCLUSIONS

Increasing the frequency of fire to meet management objectives at GBBL is an extremely difficult task, given the many constraints on the use of fire at and around Moody AFB. This plan outlines some potential approaches, but will require skill, dedication and some creativity to carry it through to implementation. Public outreach and education about the role of fire may also be necessary, especially for neighboring landowners. “Fire-wise” community programs have successfully accomplished this effort in some places, and may be a good model for the Grand Bay-Banks Lake area. The study on the presettlement fire regime of GBBL (Attachment A) can be used as an educational tool, by emphasizing the

long history of fire at the site. Coordination between the Council members will also be key to successful implementation of this plan.

ACKNOWLEDGEMENTS

Thanks to all who provided information for this plan. We'd like to thank the following individuals: Scott Duggan and Wes Abler, GA DNR; Greg Lee and Mike Burton, MAFB; Chris Strom, South GA RDC; Chris Mock, SE GA RDC; Elaine Hallisey, GA Dept of Human Resources; Scott Sherman and Dale Jobes, GEMA. We'd also like to give thanks for assistance in GIS problem solving: James Douglas, AL TNC; John Prince, SRO TNC; Jean Brock, Jones Ecological Research Center.

Figure 1: Smoke-sensitive Areas

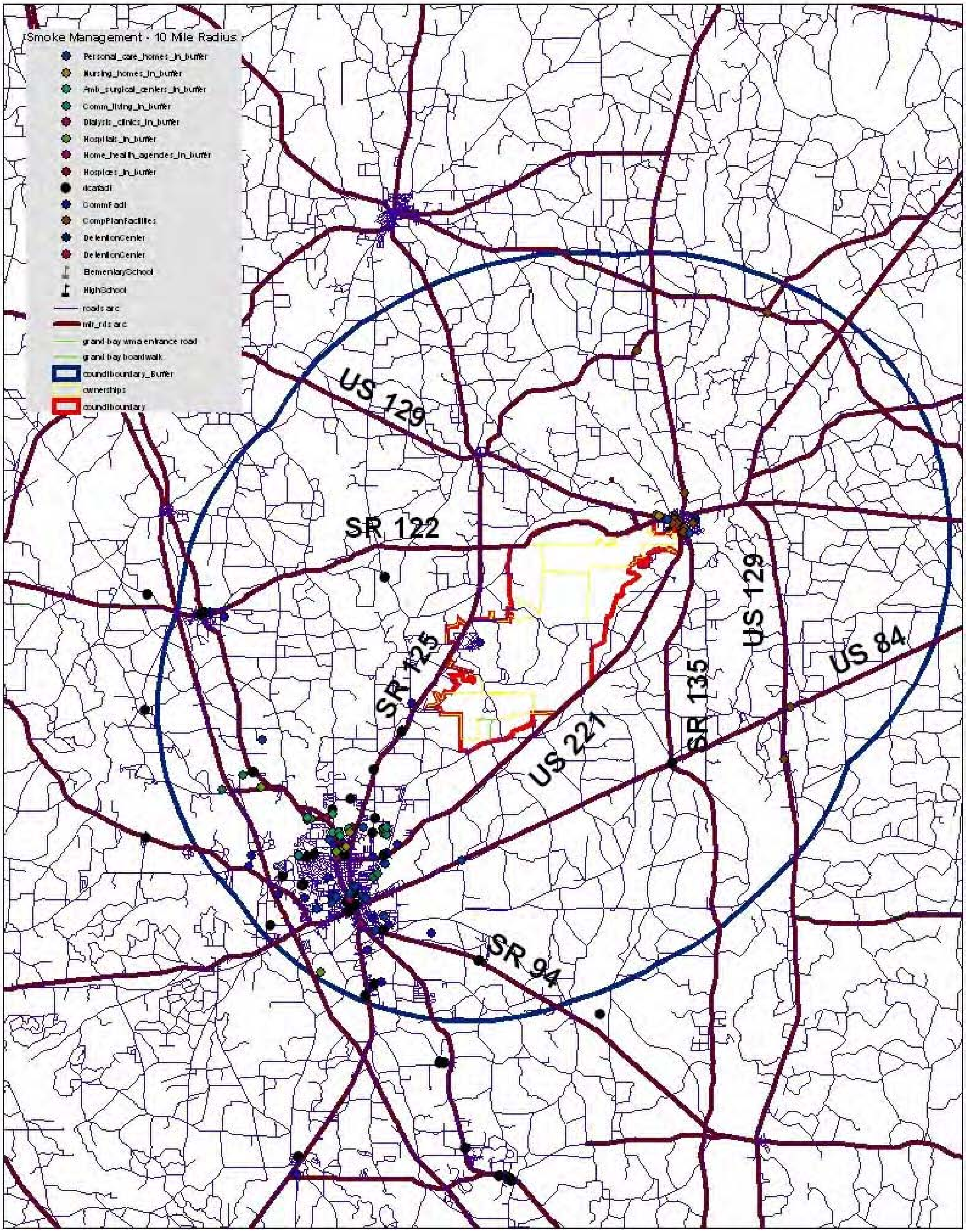


Figure 2: Fire Management Zones

Figure 3: Current Vegetation

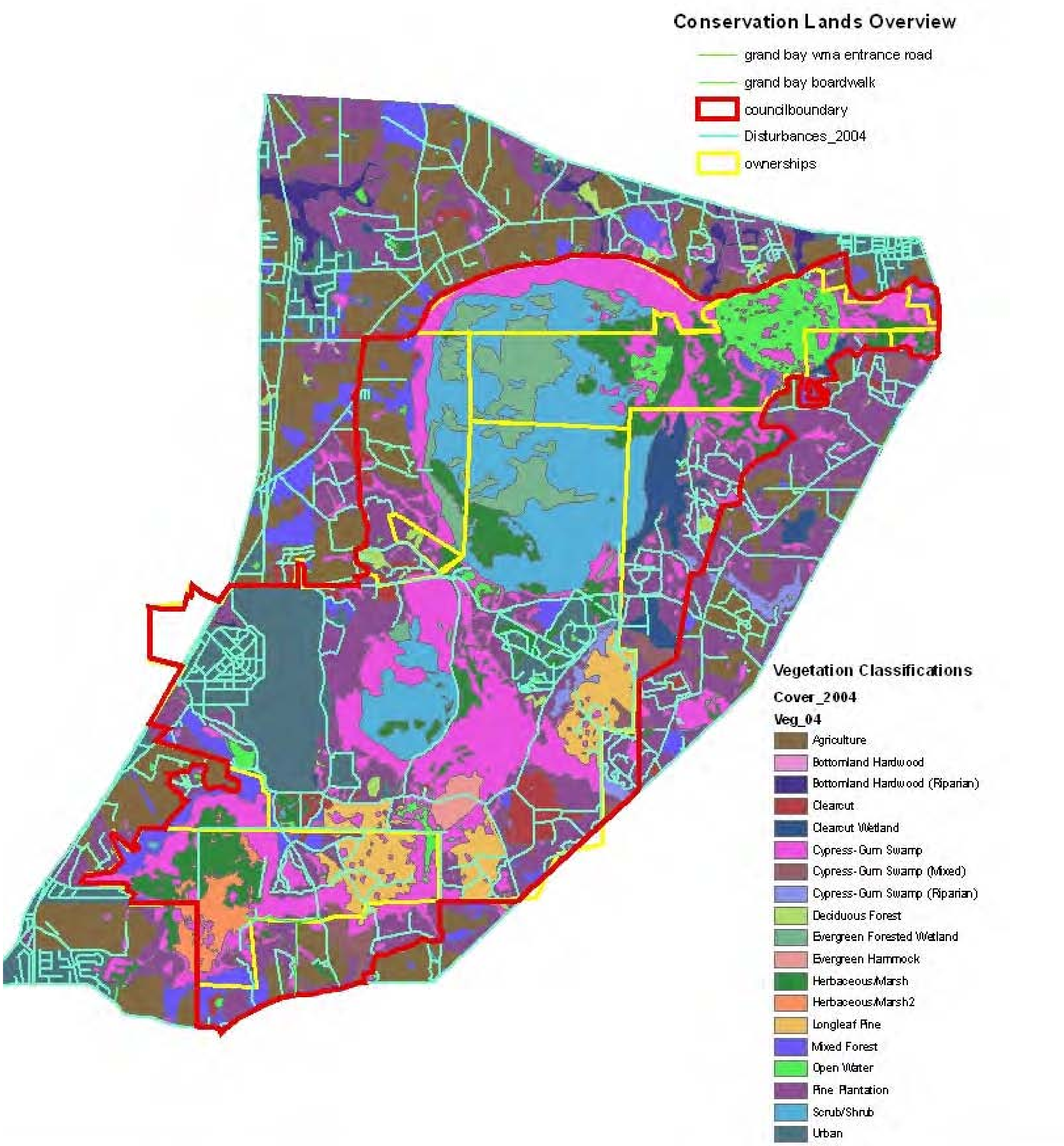
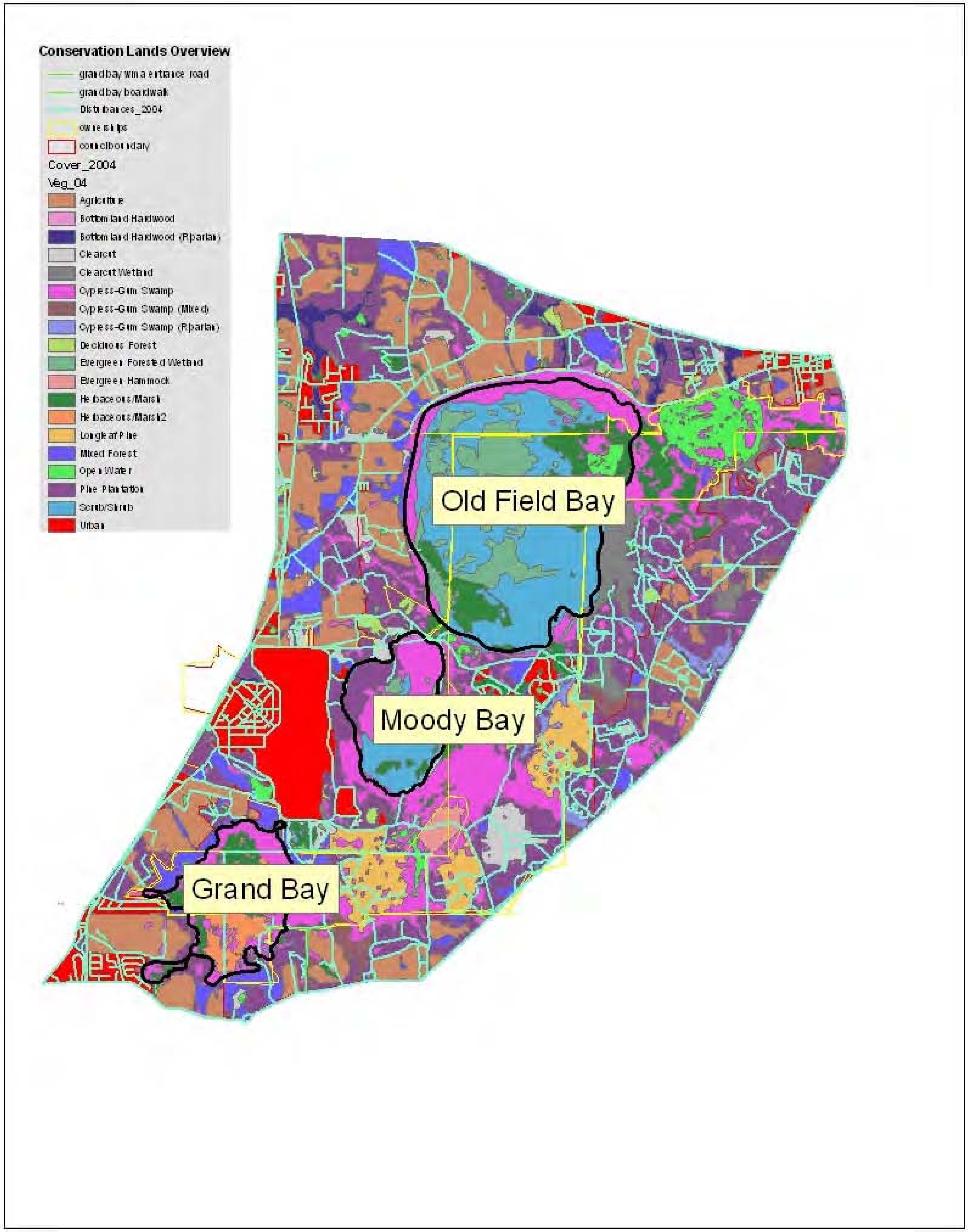


Figure 4: Grand Bay, Moody Bay and Oldfield Bay



Grand Bay-Banks Lake Strategic Plan
Monitoring Component

Monitoring Plan for Grand Bay-Banks Lake

Alison McGee and Jeff Spratt

INTRODUCTION

The Grand Bay-Banks Lake ecosystem is a large and complex area that would require tremendous resources to adequately monitor all system and species targets. As resources are limited, measurement of conservation success will focus on a small number of species and include limited on-the-ground sampling to tract changes at the systems level. Results of the project monitoring efforts as well as continually developing information will be used to re-evaluate objectives and actions on a frequent basis.

Abundance of round-tailed muskrat (*Neofiber alleni)*

Methods:
House counts done by helicopter or airboat are the best way to determine population size. Counts should be done in spring before wetlands "green up." Only houses with some green vegetation incorporated into the structure should be counted. Monitoring programs in south Georgia currently use an estimate of 2.2 active houses per rat (Birkenholtz 1963).
Frequency and Timing: Every 1-2 yrs in spring
Location: Grand Bay, Rat Bay, Oldfield Bay, other possible habitat
Who monitors: DNR, MAFB

Abundance of Sandhill Cranes (*Grus canadensis*)

Methods:
All marsh habitat surveyed for cranes in April by helicopter or by airboat. Helicopter surveys conducted at low (35m?) elevation and designed to systematically cover all available habitats. Sight correction factor should be used. April was selected as the survey period due to the increased visibility of nesting cranes, absence of leaf cover and new emergent marsh vegetation, and absence of migrant greater sandhill cranes (G. c. tabida)
Frequency and Timing: Every 1-2 yrs in April

Abundance of Greenfly orchid (*Epidendrum conopseum*)

Methods:
To be developed by Resource Managers
Frequency and Timing: Every 1-2 yrs in spring

Long-term Vegetation Monitoring

Methods:
Photopoint Monitoring- Long-term monitoring for the Grand Bay Banks Lake ecosystem will include photopoint documentation. The use of photopoints will provide a straightforward, easily repeatable method to document the changes to a particular site over time due to altered hydrological management or a significant event such as prescribed fire. Photopoints will be established at target areas to adequately cover the GBBL ecosystem. The photopoints will be located at permanent

fixtures when possible; such as water control structures. Where permanent structures are not available, small wooden stakes will be driven into the ground at the location.
The photos will be taken with a Ricoh GPS camera with automatic image geo-coding. The photos will be watermarked with latitude and longitude, direction photo was taken, name of the photopoint area, elevation, date, and any additional comments that may be needed. ESRI ArcView extension for hot linking shape file to images will be used. The establishment of the photopoints and the first reference photos will be occur during the last two weeks of April, 2006.

Frequency and Timing: Photos will be taken at five year intervals. When prescribed burning will be performed, photos will be taken immediately prior and after the event. Due to the limitation of detail in using photos to determine species, detailed notes will be recorded to allow for thorough descriptions of the sites.

PRESETTLEMENT VEGETATION AND NATURAL FIRE REGIMES OF THE GRAND BAY/BANKS LAKE NATURAL AREA

Report Prepared for

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May 15, 2006

ACKNOWLEDGEMENTS

Thanks are due to Alison McGee for copies of soil and topographic maps, photos and other background materials, to Tip Hon for discussion of water control structures and alterations in hydrology of the site, to Nedda Hon for access to Grand Bay and the use of her thesis and visitors' guide to the Grand Bay Education Center lands, to Amy Squire, University of Georgia for providing digital copies of 1941 and 1943 aerial photos and GIS layers, to Justin Jacobs of the South Georgia Regional Development Commission for preparing a map of elevations based on DEMs and for preparing a special GIS map allowing location of the original 1820 Land Lot lines and the virgin forest witness trees recorded on the first survey. Thanks to Ben Strickland for access to the hardwood slopes on his farm at the western edge of Old Field Bay. Thanks also to staff of the Georgia Archives in Morrow, Georgia for assistance in searching the original land survey plats and surveyors' notes, beginning with the very first survey of Erwin County Districts 10 and 11 for the Land Lottery of 1820.

DISCLAIMER

The findings and opinions expressed herein represent the interpretations and professional judgments of the author. These are not necessarily representative of the policies or opinions of The Nature Conservancy, the Air Force, the Georgia DNR Wildlife Resources Division or the U.S. Fish and Wildlife Service.

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EXECUTIVE SUMMARY

Project Title: PRESETTLEMENT VEGETATION AND NATURAL FIRE REGIMES OF GRAND BAY/BANKSLAKE

PRINCIPAL INVESTIGATORS: Cecil Frost and Susan Langley

OBJECTIVE: The goal of this project was to develop maps of the original vegetation and original fire regimes of the Grand Bay-Old Field Bay-Banks Lake wetland complex to provide a background for decisions around restoration and land management. Rather than mapping existing vegetation, the intent was to produce the best approximation of the natural vegetation that existed at time of first European settlement. This is the vegetation that dominated the landscape prior to 1820 and for some 6,000 years before. Understanding original vegetation is essential to restoring habitats and managing lands for perpetuation of rare species, natural vegetation communities, and for the full range of animal and plant species that depend upon them for habitat. Nearly all the upland original vegetation of the natural area was in some way structured by fire. About 65% of rare native plants and animals in the South are in some way dependent upon fire to create or maintain their habitat. Since the site contains a number of these species and habitats for some species now extirpated, the GIS layers can serve as base maps for guidance in protecting endangered species and wildlife habitats. They can also serve as a guide to managing and restoring examples of the longleaf pine ecosystem, canebrakes, bay-galls, swamps and the other natural vegetation communities and wildlife habitats originally present. A new mapping method using landscape fire ecology was used to reconstruct presettlement fire frequency (Map 1) and presettlement vegetation (Map 2). This involved field sampling of the best remnant vegetation on each of the 26 soil series shown on the portions of the two county soil maps that cover the area; compilation of historical information relating to vegetation; characterizing fire effects in each kind of vegetation on each soil series; mapping regional and local fire compartments; and identification of fire-frequency indicator species and fire-frequency indicator plant communities. Soil series were then used to put boundaries on vegetation types. Data collected from several hundred plots during previous work at other sites in the mid-Atlantic region were used in interpreting vegetation. Descriptions were prepared of the original vegetation types of the natural area as they occurred on each soil series. The presettlement vegetation method used here is expected to have application throughout the South and in other landscapes where frequent fire was an important determinant of vegetation in presettlement times. Forestry staff at Moody Air Force base and the Georgia DNR Division of Wildlife Resources have begun a program of management for natural forest types, and for restoring natural processes such as fire. Using the maps as guides for habitat restoration, the cooperating agencies should be able to establish management policies that will meet national defense, wildlife, recreation and other management objectives while restoring natural fire regimes and maintaining examples of the full range of rich natural communities that the area first encompassed. Grand Bay itself was found to be unique among the wetlands of the natural area, being a true clay-based Carolina bay, with its flat basin perched above the rest of the bays and originally supporting extensive graminoid zones with scattered slash pine maintained by frequent fire.

INTRODUCTION

In the southeastern U.S. it is possible to reconstruct original vegetation and natural fire regimes, even where human land use practices have radically transformed upland vegetation. This is feasible even without witness tree records from early surveys, because of the pervasiveness of fire in the presettlement southeastern landscape and the predictability of fire in shaping vegetation. Given topography, modern soil maps, natural vegetation remnants, and any available historical background, a close approximation of original forest and other vegetation types can be obtained (Frost 1998, 2000).

The landscape now occupied by the Grand Bay/Banks Lake natural area is complex, in soils, topography and geomorphology, but has lost some of the associated complex natural vegetation and species diversity as the result of disturbance and twentieth century fire suppression. Still there are enough historic materials, remnant native species and natural plant community fragments on the site, as well as information from natural vegetation on similar soils elsewhere in the region, to adequately reconstruct original vegetation.

In a long-disturbed landscape, reconstructing historic vegetation requires synthesis of every shred of available physical, vegetational and historic information. It also requires interpretation of the role of fire using methods related to landscape fire ecology. The overall region of which Grand Bay and Banks Lake are a part originally experienced a 1-3 year fire frequency on upland sand ridges, upland flats, and in some of the included bays and other small wetlands. On the other hand, despite frequent fire on the most fire-exposed uplands of the landscape, a network of natural firebreaks and subtle differences in topography, particularly below the scarp bounding the natural area on the west, led to reduced fire frequency over substantial parts of the landscape. Reduced fire effects in the vicinity of steep bluffs, such as those along the west side of Old Field Bay, permitted the coexistence of frequent fire types like longleaf pine/wiregrass on uplands, in close proximity with less fire tolerant hardwood such as pignut hickory (*Carya glabra*) on partially fire-protected parts of the landscape, and even magnolia (*Magnolia grandiflora*) and spruce pine (*Pinus glabra*) on the most fire sheltered slope toes and hammocks. The objectives of this study were:

1. Determine the community types and species composition of original vegetation types and their soil, topographic and fire relations,
2. Reconstruct the generalized presettlement fire regimes for the natural area, and
3. Create a presettlement natural vegetation map at the resolution of the soil series.

The resulting presettlement vegetation map was prepared as a GIS layer to serve as reference conditions for use in planning, in future studies, and in restoration and management of natural forest communities and wildlife habitats. The maps can also be used to help delimit habitat for endangered and threatened animals and plants. The project also constitutes a demonstration of the landscape fire ecology method for reconstruction of presettlement vegetation and fire frequency regime, and illustrates the applicability of this new method for public lands, natural areas and preserves throughout the southeastern U.S.

Place names. Appendix 1 lists historical and modern place names in the Grand Bay vicinity. This includes several Native American place names recorded by the first surveyors in 1820. For convenience I will use the following names in the text for the wetlands in the study area (listed from northeast to southwest..

Milltown Bay – after a former name for Lakeland
Banks Lake – originally Lee's millpond, named for its third owner, Henry Banks
Old Field Bay – originally Lopahachy Swamp (Native American name), and Grand Bay to the settlers (on an 1863 deed), but current names used by managing agencies will be used throughout this report.
Moody Bay – no other name encountered, may have just been considered part of Grand Bay to the settlers.

Rat Bay – water management unit between Moody Bay and Moccasin Bay named by Georgia Division of Wildlife Resources for a population of water rats living there.
Moccasin Bay – water management unit at the head of Grand Bay Creek named by Georgia Division of Wildlife Resources
Dudley Bay - water management unit named by Georgia Division of Wildlife Resources for Dudley's Hammock which it surrounds.
Grand Bay – clay-based bay at the Georgia Division of Wildlife Resources Education Center. No other historical name encountered during a cursory historical search but it was unique enough that it may have had its own name at some point in history.

In addition to Banks Lake, Old Field Bay, Moody Bay, Rat Bay, Moccasin Bay and Grand Bay all have had managed water levels. The names refer to management units and are useful for talking about the site. Moody Bay and Rat Bay appear to have been part of the same bay before being divided by construction of Air Force crash trails around 1941. Dudley Bay seems to be just a slightly impounded portion of the original drain from Grand Bay into Grand Bay Creek, and Moccasin Bay seems similarly to be a slightly impounded area at the head of Grand Bay Creek where it leaves the bay complex. So the five major natural bays in the original landscape would have been Milltown Bay, the deep bay that is now Banks Lake, Old Field Bay, Moody Bay and Grand Bay. This not to mention the numerous smaller bays and lime sink depressions in the vicinity such as Monk's Pond, Fish Pond Bay and Becky Bay. Old Field Bay seems to have been the original Grand Bay, being referred to on early deeds.

HISTORICAL RECORDS RELATING TO ORIGINAL VEGETATION OF BANKS LAKE AND GRAND BAY

Historical materials available. Historical survey records for Lowndes County are available at the Clerk of Courts office in Valdosta. The courthouse burned in 1859 so records before that date were lost, with exception of the original land lot surveys. All records for Lanier County prior to its formation in 1920 are still in the Lowndes County courthouse for the portion of the county that came from Lowndes. Records for the portion that came from Berrien are in the Berrien Clerk of Courts office at the courthouse in Nashville. The original District 10 and 11 surveys along with the surveyors' original notes were examined in the Georgia State Archives at Morrow, GA. Excellent, high resolution images of the two canvas survey maps are available and can be downloaded online. A set of historical maps of Georgia ranging from 1747-1895 were obtained on CD from the Georgia Archives at Morrow, GA (Georgia Archives 2004).

First settlement. Georgia did not have counties until 1777. Prior to that time, from 1732 to 1758, the settled areas along the Atlantic coast were divided into districts and towns. From 1758 to 1777, Georgia was divided into twelve parishes, After 1777 the twelve parishes became the original seven counties of Georgia, which include: Burke (St. George Parish), Camden (St. Thomas and St. Mary Parish), Chatham (St. Phillips and Christ Church Parish), Effingham (St. Matthew and St. Phillip Parish), Glynn (St. David and St. Patrick Parish), Liberty (St. John, St. Andrew, and St. James Parish), and Richmond (St. Paul Parish). In the interior Georgia counties near the Gulf Coast settlement was prevented until the relatively late date of 1821 because the land was claimed by Spain and occupied by the Creek Indians and related tribes. Several treaties with the Indians and cession of the Spanish lands to the U.S. opened up a vast region of Georgia, Alabama and Florida for settlement, including the Grand Bay vicinity. Georgia's population had reached 40,000 people in 1776 (Coleman 1991) and the population had grown large enough to create pressure for settlement of the interior lands by the 1820's.

Irwin County was formed in 1818 to take advantage of the new lands being opened up. Never occupied by the Spanish, the Irwin County region was formed from Indian land. This was a large county that extended

from the present location of Irwin County to the Florida line. Berrien, Lowndes and Lanier were formed later, in part from this original larger county.

Lands in the central and western thirds of Georgia were distributed in land lotteries. Lowndes county was formed from 506 sq miles of Irwin county on December 23, 1825 and lands in Lowndes were distributed in the Land Lottery of 1820. Lands were surveyed in 1819, 1920 and 1821. There followed an amazing amount of reshuffling of counties and county boundaries: Lowndes later gave up lands to Berrien, Brooks, Clinch, Colquitt, Echols Lanier and Thomas. Berrien was created in 1856. Lands toward the formation of Lanier county were given much later, and Lanier county was not officially created until November 2, 1920, with lands from Berrien, Clinch and Lowndes counties (Bryant, 1983, pp. 72 and 75).

For survey purposes, Irwin county was divided into districts and each district was surveyed into 490 acre Land Lots. The natural area falls into the southern two tiers of District 10 and the northern 9 tiers of District 11 (see Figures 3 and 4). Lots are numbered in the order in which they were surveyed. The District 10 surveyor numbered lots from west to east and the numbering wraps around and continues in sequence where the surveyor doubled back at the end of each run. The surveyor for District 11 numbered them from north to south.

Historical maps. Tanner's 1839 map of Georgia and Alabama shows no towns between the Withlacooche and Alapaha rivers and is the first to show Grand Bay Creek which it calls "Irwin's River". An 1850 map of Georgia also shows no towns between the Withlacooche and "Allapahaw" rivers.

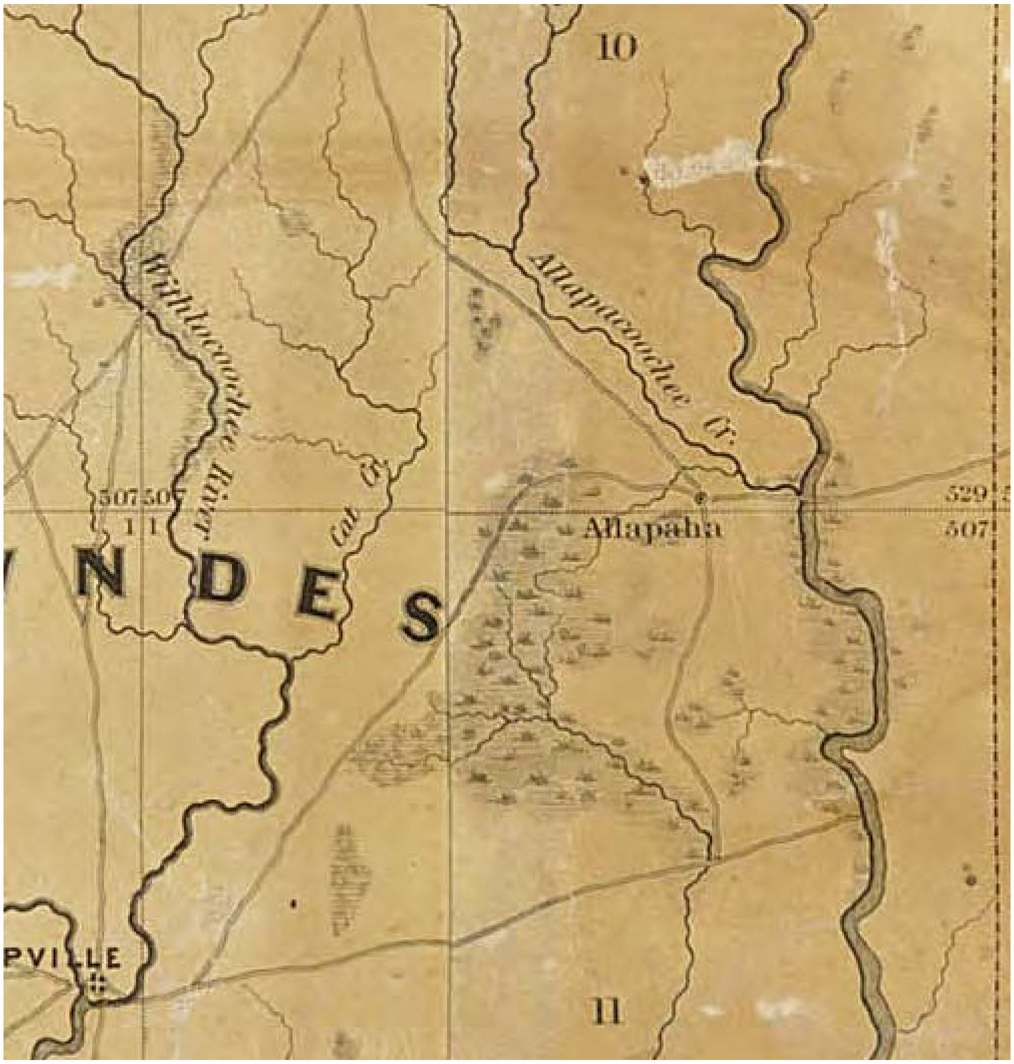

Figure 1. is a portion of the Bonner map of 1847 and is the first to show the Grand Bay wetlands. Bends of the Alapaha River are better represented than on the original 1821 survey and the original Indian name of Allapacoochee Creek is used for what is now called, regrettably, Big Creek The town of Allapaha (now Lakeland, not to be confused with the original Indian town of Alapaha a few miles to the north), shows the east/west coach route to Troupville. The coach route, which was the forerunner of SR 122 and 125, wrapped around the northern curve of Grand Bay (Old Field Bay) and ran south along the sandy ridge through what are now Barretts, Moody AFB and Bemiss, south to Troupville (Valdosta had not yet been founded). In Old Field Bay there is a shown a divide, with waters from the Peters Bay vicinity draining north into Mill Creek and the southern end having a drain originating in the vicinity of what is now Shiner Pond, another originating on the sandy scarp to the west, another in Grand Bay, and a north/south drain that may be Wide Branch, all draining into the head of Grand Bay Creek. All subsequent maps show this divide.

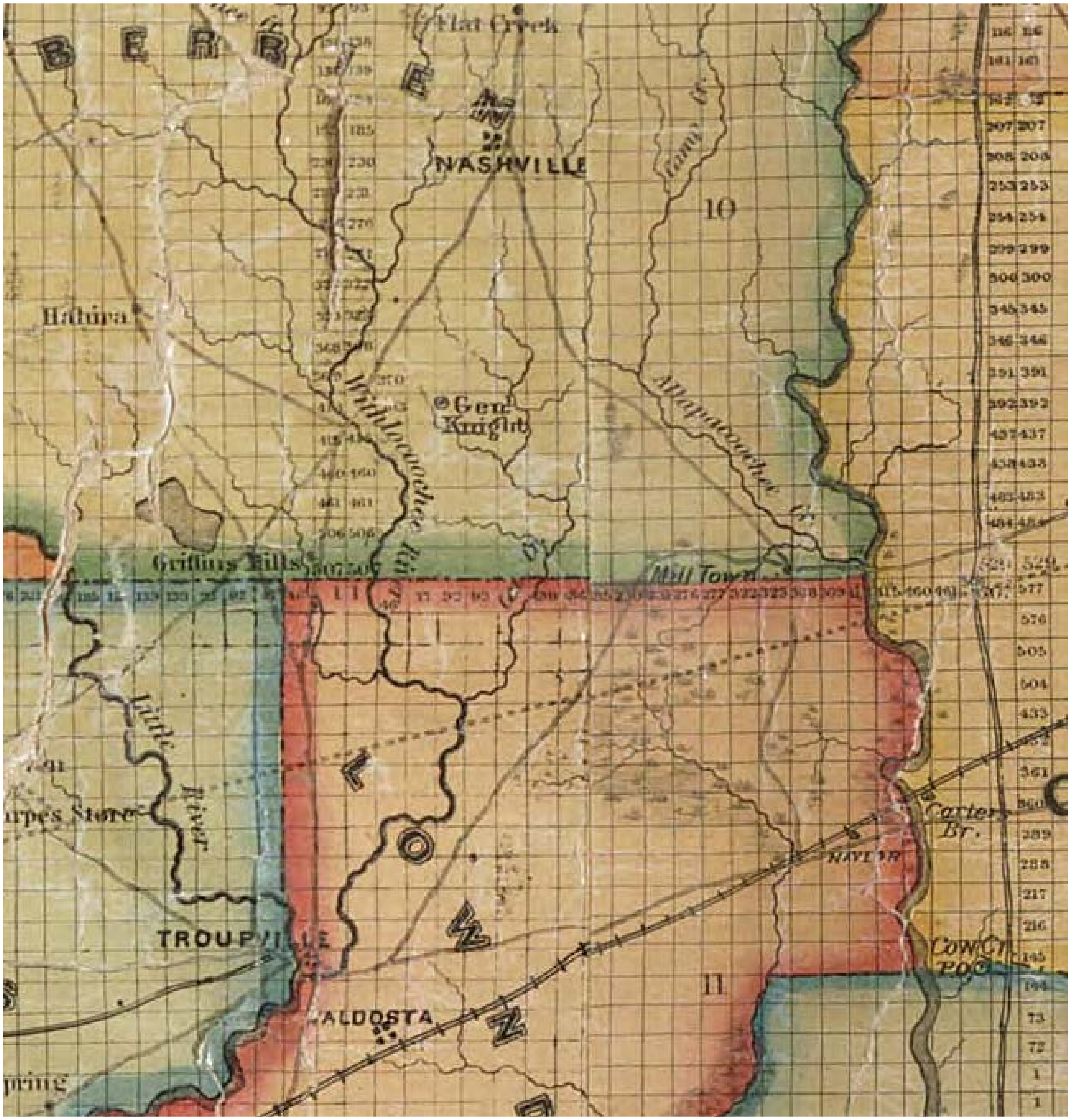

Figure 2. The J.R. Butts map of 1870 shows the Land Lot grid and the Savannah and Gulf Railroad which had been completed just before the Civil War. The railroad first appears on the 1863 Johnson map and parallels the modern route of U.S. 84. The turpentine still shown in Figure 7 below was located on this line at Indianola, a stop between Naylor and Valdosta and due south of the Grand Bay education center.

Indians. Prior to settlement the major Native American groups in the Grand Bay vicinity were the Apalachee to the southwest, Yamasee to the northeast and Lower Creeks to the northwest (Coleman p. 29). The Seminoles were formed much later, originating as an assemblage of several groups of Creek Indians who moved south in the late 18th and early 19th centuries into Florida after it had been depopulated of its original Timucuans. Grand Bay was in an area near the boundary between the Apalachee and remnant

Timucuans and the original inhabitants of the Indian town Alapaha, in what is now Berrien County, were the sad remnants in 1820 of what had been a widespread culture.

Despite their broad original range, from south Georgia to the Atlantic and Gulf coasts of much of Florida, only a little is known about the Timucuas, perhaps because of their having had the honor of being decimated by European diseases earlier than any other southeastern tribes. Only a few words of their language are known, along with an a few miscellaneous facts, such as that their women wore skirts woven of Spanish moss. The Spanish introduced diseases to which the natives had no resistance, including smallpox, measles, typhus, tuberculosis, chicken pox and influenza, any of which could prove fatal. When the southeastern Indians were hit with smallpox, at least 30% died (Hudson 1976). Timucuans were the first to be exposed to western diseases, beginning in 1528 when Panfilo de Narváez landed with 300 men to attack Indians in Timucuan territory near Tampa Bay. He went on from there to plague the Apalachee Indians on the Gulf Coast to the north. Narváez, and shortly later, de Soto reported evidence of Indian depopulation in Florida. In Tampa, in 1539, de Soto picked up a Spaniard, Juan Ortiz, who had been captured by the Timucuas during the Narváez invasion 11 years before and had become fluent in Timucuan, and used him as an interpreter. The Timucuans became the first to experience de Soto's pattern burning of villages and torture of survivors as he traveled north into Apalache territory and on into southwest Georgia and beyond, where his exploits have been well documented.

Timucuans were contacted again in 1594 by French Huguenots near the mouth of the St. John's River in Florida. "The Huguenots tried to convert the Timucuans to Protestantism. The Timucuans taught the Huguenots to smoke tobacco." By 1655 Spanish Franciscans had established 38 missions in the provinces of Timucua, Guale (coastal Georgia) and Apalachee (Florida panhandle)(Hudson 1976).

> "In 1702, James Moore of South Carolina systematically destroyed Spanish missions all the way down the coast to St. Augustine, and in 1704 he led what was perhaps the most devastating raid ever mounted against the Southeastern Indians. He set out on what later became known as the Lower Trading Path with an army of 50 whites and 1,000 Indian mercenaries. They moved from South Carolina across Georgia into Florida, destroying Spanish missions and fortified Apalachee towns as they went along. In all, Moore's men destroyed thirteen missions; killed several hundred Indians and Spaniards, many of whom were tortured to death; enslaved 325 men, women and children, and relocated more in Carolina. On a smaller scale the Carolinians continued these raids for several years. By 1710 the Apalachees, Timucuas, Calusas and other Florida Indians were completely shattered and Florida was unoccupied except for a few survivors huddled around St. Augustine" (Hudson 1976 p. 436).

There were still a few Indians in the Banks Lake vicinity at the time of survey and the surveyors likely met and talked with them, recording their names for local features. Most of the creeks on the survey maps are shown with their original Native American names. Examples include Lopahachy Swamp for Grand Bay (the Old Field Bay portion) in the District 11 surveyors notebook and Allapacooche for Big Creek (Allapucoocha on the District 10 map) . Mill Creek was labeled Fork of Allapacoochee" on the District 11 map. Alligator Run was called Allacooche in one of the surveyor's notes. With exception of Camp Creek, the eastern branch of what is now called Big Creek, Cat Creek was the only stream with an English name.

In addition to the Spanish lands cession in 1821, a treaty signed with the Creek Indians also facilitated opening lands for settlement. One surveyor's field note book begins with "Field notes on a survey of the Eleventh District, Irwin County—a part of the late land Territory obtained from the Creek Indians at a treaty held and Concluded at the Creek agency—Commencing the 21st November 1819" (J.H. Brodnax 1819 p. 1). The treaty referred to was largely a sham, devised to get the remaining Indians out of the way of progress, and occurred without the knowledge or consent of the majority of the Creeks (Coleman 1991).

Given this history, and flooded with settlers such as Joshua Lee, builder of the first Banks Lake millpond, taking up their 490 acre plots obtained in the 1820 land lottery, the last remaining Indians resorted to unpleasantness. Their resistance was suppressed in summer 1836 when "Marauding Indians plundered the plantation of William Parker near Milltown [Lakeland]". Militia overtook them near Gaskins Pond near the Alapaha River and killed several. A few days later the militia found a few more Indians at Brushy Creek and "…ran them off. That was the last real battle with the Indians in this section" (from Georgia Historical Commission marker outside the Berrien County courthouse).

Banks Mill Pond. Joshua Lee (1782-1855) obtained 5 ½ land lots totaling 2,690 acres "*which was not yet free of Indians*". Sometime between 1827 and 1835 Lee constructed a dam to run the first grist mill on the old stagecoach road from Waycross to Thomasville (Georgia Historical Commission marker). The mill dam was constructed at the head of Mill Creek near where SR 122 crosses it today. This dam flooded a flat bottomland creating what is now known as Banks Lake. The first known sawmill was added to the grist mill by William Lastinger in 1848 (Lowndes County Deed Books). In 1838 a post office was built, establishing the town of Alapaha. The name was officially changed in 1857 to Milltown, which had apparently been in use for some time before that, and later became Lakeland in 1925. See the chronology in Appendix 2 for a summary of events in the history of the pond and the rest of the natural area.

VEGETATION INFORMATION FROM THE LAND LOTTERY SURVEYS 1819-1821

Early surveys in each state and at different times within the settlement of Georgia, depending upon directions given the surveyors, have their own quirks. In surveys of the mid 1700's on the Atlantic Coastal Plain of Georgia, surveyors routinely gave a descriptive name to each major vegetation type on surveyed lands and drew in rough boundaries between types such as "pine land", canebrake, "oak and hickory land" and swamp. While this kind of information was not included in surveys for the 1820 Land Lottery, the major vegetation associations can be inferred from the tree species along the survey lines and wetlands were often colored in. In addition, the two surveyor's record books in the State Archives have a few bits of information not found on the maps. The term "bay-gall", used for fire-influenced evergreen shrub and bay vegetation, is found several times in the record books but was not used on the maps.

Figure 3.   A portion of District 10 1820 Land Lot survey map. The north/south drain on the left is Cat Creek. From the upper center, Big Creek drains southeast into the Alapaha River. At lower right, Mill Creek is called “Fork of Allapacooche” (Allapacooche was Big Creek). Lots are numbered in their centers. At lower right, lots 522 and 523 include the northern half of Milltown Bay which is shown as a slightly darker shade than the rest of the map. At bottom center, lots 517, 518 and 519, also shaded, include the northern curve of Old Field Bay and its wet drains to the north. At the juncture of lots 446 and 447 (lower right center), Berryhill Pond can be made out, along with its drain Alligator Creek which can be traced south into Old Field Bay. Wetlands and stream drainages are much more reliable on this map than on that for District 11 below.

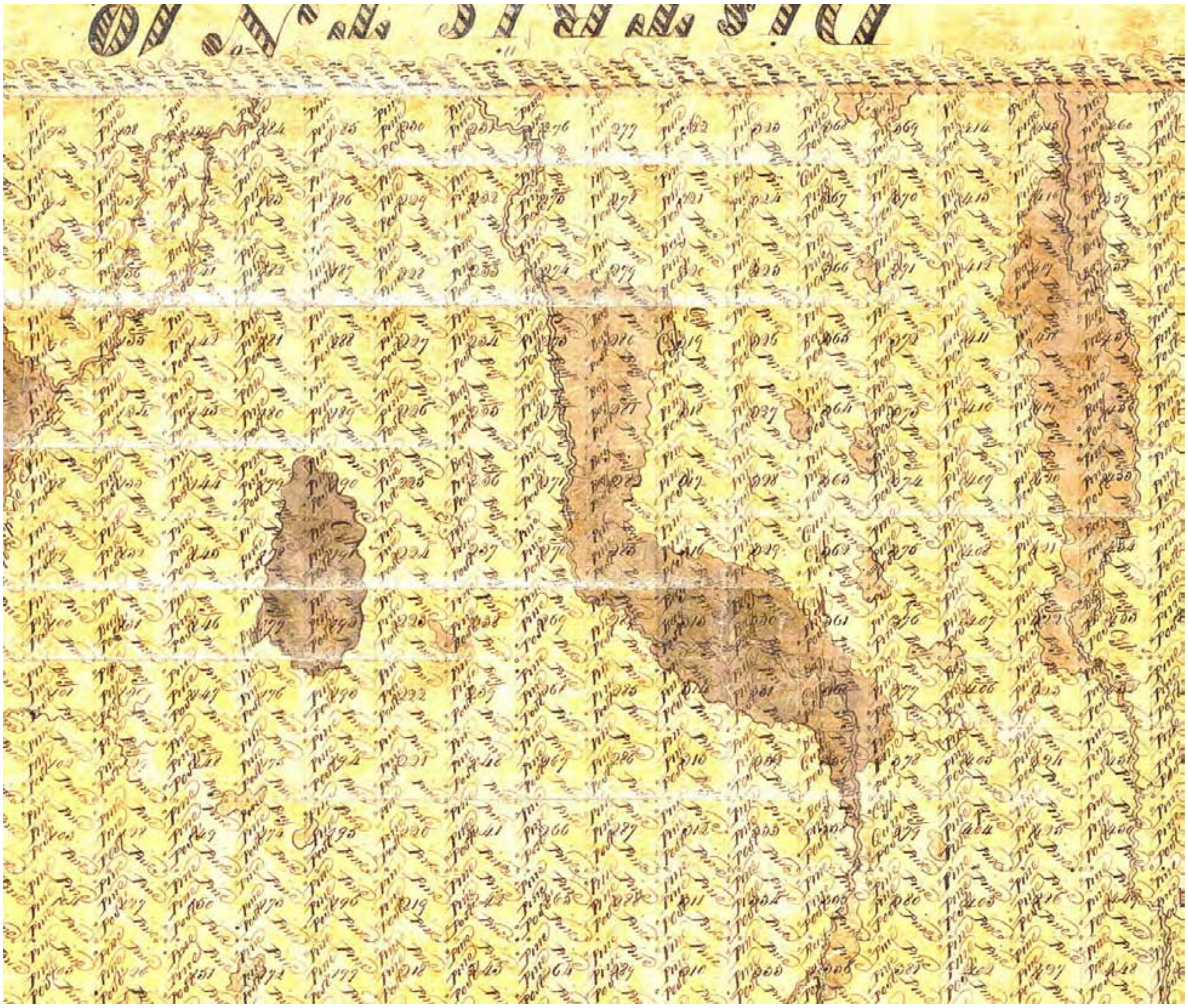

Figure 4. A portion of the District 11 1821 map. Streams and wetlands are more crudely drawn than on the map for District 10 and both are less accurate. Wetlands are shaded. Cat Creek enters Lot 139 at upper left. The apparent loop in the creek is formed by a swampy wetland on the east side, while the actual creek is the western half of the loop. Grand Bay is the isolated oval wetland in left center including portions of lots 177, 178, 179, 191, 192 and 193. The large drain in the center is an attempt to represent Old Field Bay and the wetlands between it and Grand Bay Creek, which can be seen flowing south out of the area. Note that the survey shows a drain leading into the northern part of Old Field Bay (now inundated) on its western side, which flows south and then east to become Grand Bay Creek which then flows south out of the natural area. The small half oval wetland on the upper right boundary is the southern half of Milltown Bay. No shading is given to the Banks Lake area (Lots 323 and the western half of Lot 368), which was mostly forested bottomland. The Alapaha River bottomland is shown on the far right.

DISTRICT 10 (northern part of the natural area)		
TREE NAME	**NUMBER**	**INTERPRETATION**
L.W. or Lightwood	6	Longleaf pine (*Pinus palustris*). This name was used only by the surveyor for District 10 – the two northern tiers of land lots of the natural area including Lakeland and the northern edges of Milltown Bay, Banks Lake and Old Field Bay. Reported 4 times on dry uplands, once on a point of land between Milltown Bay and Banks Lake and once on the now drowned western Carolina bay sand rim of Banks Lake, suggesting access by fire in the original landscape.
"Pine" (uplands)	71	Interpreted as longleaf pine when on fire exposed uplands.
"Pine" (wetlands)	16	Interpreted as mostly slash pine (*Pinus elliottii*) because of the types of habitats where the surveyor found it and the prevalence of fire in the original system, but also with some loblolly pine on moist flats and toes of steeper slopes in Old Field Bay which provided a partial refugium from fire. Also includes a small amount of pond pine, mostly in wet mixed-pine savannas.
Cypress	6	Pond cypress (*Taxodium ascendens*). Cypress appears to have been scarce in the original landscape. The surveyor reported it once in a small depression pond, twice in Milltown Bay, and twice in small drains to the north of the natural area and once in the original run of Milltown Creek (the portion now under Banks Lake)
Gum	9	Judging by the habitats where it is used, the District 10 surveyor seems to consistently have used this name for swamp black gum (*Nyssa biflora*) (the name for swamp black gum seems to change to "bay" just on the District 11 side) Since the name "gum" appears so seldom on the District 11 map it may refer there to sweetgum (*Liquidambar styraciflua*) which would have been a relatively minor component of wetland forests.
Bay	9	Sweet Bay (*Magnolia virginiana*). May have included an occasional Magnolia grandiflora but chances of encountering it on a survey line were slim given its fire-refugial habitat and very limited extent in the original fire landscape. On the District 11 map this seems to also have included swamp black gum.
R. Bay	4	Red Bay (*Persea palustris*)
"Titie"	1	Black Titi (*Cliftonia monophylla*) and/or Titi (*Cyrilla racemiflora*). In the Alapaha River swamps
R.O.	1	Southern red oak (*Quercus falcata*). Surveyors often used abbreviations for the oaks such as W.O., R.O., B.O., P.O. and Wtr.O. Only a single oak was noted within the study area by the surveyors – in a small, partially fire sheltered upland ravine north of S.R. 122 leading south into Old Field Bay.
TOTAL	123	
(Maple)	(3)	Red maple (*Acer rubrum*) only in the Withlacoochee River swamp outside the natural area.

Table 1. Eight tree names used by Charles McKinnon, surveyor of District 10 of the 1820 map (the northern two tiers of land lots of the natural area), resulting from the Georgia Land Lottery of 1820. This was District 10 of Irwin County, covering the portion of the natural area now in Lanier County.

DISTRICT 11 (southern part of the natural area)		
TREE NAME	**NUMBER**	**INTERPRETATION**
"Pine" (uplands) (total = 284)	44, 31, 35, 35, 31, 33, 29, 36, 10	Interpreted as longleaf pine when on fire exposed uplands.
"Pine" (wetlands) (total = 107)	22, 15, 13, 11, 16, 10, 13, 6, 1	Interpreted as mostly slash pine (*Pinus elliottii*) because of the types of habitats where the surveyor found it and the prevalence of fire in the original system, but also with some loblolly pine on moist flats and toes of steeper slopes in Old Field Bay which provided a partial refugium from fire. Also includes a small amount of pond pine, mostly in wet mixed-pine savannas, and perhaps one stem of Pinus glabra in Dudley's Hammock.
Cypress	3	Pond cypress (*Taxodium ascendens*). The surveyor reported it only three times, all on uplands (probably small depression ponds).
Gum	2 (1 on edge of Peters Bay)	Probably sweet gum (*Liquidambar styraciflua*) since it was only reported twice, on upland/wetland edges, and the District 11 surveyor seems to have lumped swamp black gum and all other smooth-barked trees under "bay".
"Bay" (Sweet bay, red bay and swamp black gum)	10, 8, 9, 9, 13, 10, 10, 3	Sweet Bay (*Magnolia virginiana*) and likely also used for red bay (*Persea*) and even swamp black gum (*Nyssa biflora*) by this surveyor. May have included an occasional *Magnolia grandiflora* but chances of encountering it on a survey line were slim given its fire-refugial habitat and very limited extent in the original fire landscape.
TOTAL	468	

Table 2. Four tree names used by John H. Brodnax, surveyor of the 1821 map of Irwin County District 11 which included the largest part of the natural area. Two survey lines intersected in Dudley's Hammock but the only two trees recorded there were "pine" (likely loblolly or *Pinus glabra*, the only place where this tree could have been encountered) and a "bay", most likely *Magnolia grandiflora* or a large sweet bay–the only bay-like trees on Dudley's Hammock.

Species	**District 10 + District 11**	**Percent**
Longleaf pine	284 + 77 = 361/591	61.1% longleaf pine on lands between Alapaha River and Cat Creek
Wetland pines	107 + 16 = 123/591	20.8%
All pines	484/591	81.9%
Cypress	9/591	1.5%
Swamp black gum, sweet bay, sweetgum, red bay, Magnolia grandiflora	22 + 74 = 96/591	16.2% (lumped because usage of names was not consistent between the two surveyors).
Red oak	1/591	0.16%
Titi	1/591	0.16%
TOTAL STEMS REPORTED	123 + 468 = 591	100%

Table 3. Summary of all trees between Cat Creek and Alapaha River. In the original landscape between these two streams, and including two tiers of land lots for Mill Creek and Lakeland on the north and bounded by the lots along Knight's Academy Road and Old State Road on the south, 591 trees were

recorded by the two surveyors. 81.9% were pines and of these 61.8% were estimated to be longleaf pine. The remaining 20.8% were likely to be, in descending order: slash pine, loblolly pine, and pond pine. The one pine stem recorded on Dudley's Hammock would have been either loblolly pine or *Pinus glabra*, seen only at this hammock during the current survey.

Summary of Tree Names and Interpretation by Sites

Interpretation of tree names and abbreviations, District 10. L.W. – Lightwood (spelled out in places on northern half of map but mostly abbreviated. Longleaf pine was sometimes called the "lightwood tree". Some surveyors in other regions used lightwood stumps as boundary line markers, when encountered, instead of live trees because of the known longevity of longleaf pine heartwood stumps (at least 50-100 years, possibly 200 or more). The surveyor also occasionally noted that he used lightwood posts as corner markers. In most cases the corners are just labeled "Pine Post". Rot resistant lightwood was commonly used by surveyors elsewhere for corner posts.

Interpretation of tree names and abbreviations, District 11. The surveyor of District 11 used fewer tree names than that for District 10. He either knew fewer species or did not bother to distinguish them. The great majority of his trees are only "Pine" or Bay" with a few cypress and an occasional "gum". He did not mention lightwood at all even though he surveyed many miles of line through country of virgin longleaf pine forest and savanna.

Milltown Bay. Two cypress were recorded near the center of the bay, perhaps along a drain leading into the Banks Lake bottomland as a tributary of Mill Creek. One longleaf pine lightwood tree or stump was indicated on a point of land on the fire exposed south side near where the original sand rim of Banks Lake began. This indicates ready accessibility of fire to the southeastern side of the bottomland that is now Banks Lake.

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
L.W. or Lightwood (longleaf pine)		1
Pine	1	3
Bay	2	
Cypress	2	
Total	5	4

Table 4. Trees recorded in Milltown Bay in 1820

Banks Lake. No water or swamp was indicated for the Banks Lake bay on the survey map for District 11 but there is some faint wetland shading in the vicinity of the Mill Creek drainage on the map for District 10. The persistence of old heartwood stumps in the lake rising from what was a wet bottomland forest strongly suggest that slash pine (and likely some longleaf and pond pine), maintained by occasional fire in the wetlands, was the dominant tree in the bottomland.

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
L.W. or Lightwood (longleaf pine)	1 on the now drowned middle rim segment of the western sand rim of Banks Lake	1 on north side.
Pine	6 scattered through the bottomland now flooded by Banks Lake	Numerous: pines (probably longleaf) were dominant on the surrounding uplands
Bay	1 near the deepest part of the current lake	
Cypress	1 shown in the vicinity of the now drowned channel leading from the mouth of Alligator Creek into Mill Creek	
Total	9	1 (+ many pines)

Table 5. Trees recorded in bottomland of the future Banks Lake in 1820. Banks Lake fell along the boundary of the District 10 and 11 surveys.

Old Field Bay. The District 10 map shows wetland shading for Milltown Bay along its northern curve but the Map for District 11 only shows wetland shading beginning in its southern, wetter half.

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
Pine	40 - likely loblolly on moist flats near western & northern edge, slash pine & others in wetter parts accessible by fire.	Numerous pines dominant on dry uplands to the west and we savannas to the east were almost certainly longleaf.
Bay	3 (District 10 surveyor), 7 (District 11 surveyor: these were probably mostly swamp black gum in District 11)	
Gum	5 "gums" were noted by the District 10 surveyor who seems to have used the term for swamp black gum. Below the District boundary nearly all wetland hardwoods become "Bays".	
Cypress	none. Cypress seems to have been limited to swamp runs and upland depression ponds.	
Total	48	numerous pines

Table 6. Trees recorded in bottomland of Old Field Bay in 1820

Moody Bay

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
Pine	16 likely both loblolly and slash	Numerous pines dominant on dry uplands to the west were almost certainly longleaf.
Bay	15	3
Cypress	none	
Total	31	3

Table 7. Trees recorded in Moody Bay in 1820

Rat Bay. This includes some wetlands to the east of Moody Bay.

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
Pine	7 likely loblolly and slash	Numerous pines dominant in moist, fire exposed savannas to the east were almost certainly longleaf.
"Bay"	8 (probably all *Nyssa biflora*)	
Cypress	none	
Total	15	numerous pines

Table 8. Trees recorded in Rat Bay in 1820

Grand Bay

TREE NAME	WITHIN BAY	ON PERIPHERAL UPLANDS
Pine	16: 9 in central areas (likely slash pine: too fire frequent for loblolly), 7 around periphery (mostly slash with perhaps an occasionally longleaf on non-flooded margins)	Numerous pines dominant on dry uplands to the west and moist savannas to the east were almost certainly longleaf.
"Bay"	4 (in wet areas, probably all *Nyssa biflora*) as used by this surveyor.	
Cypress	none, either in bay or in peripheral areas. No other tree species mentioned.	
Total	20	

Table 9. Trees recorded in Grand Bay in 1820

HISTORY OF LOGGING AND PRODUCTION OF NAVAL STORES

The first sawmill in the area was constructed in 1848 on Mill Creek. This may have been in a separate building just downstream on Mill Creek from the grist mill. A partly illegible deed appears to refer to a "middle" saw mill (Lowndes County Deed Book C, p. 6)

Figure 5 below shows the extent and condition of longleaf pine forest in Georgia in 1884. The orange areas are regions from which all commercial timber had been removed before 1880. These included lands along all the major navigable rivers and along the first railroads. Cleared agricultural lands are not shown but much of the wooded portions remaining in the area shown in dark green represented virgin pine forest.

Though not yet logged, much of the standing timber was just beginning to be boxed for turpentine. Sargent estimated that the areas of dark green contained 16.8 billion board feet of virgin longleaf pine timber as of 1880. The annual cut in Georgia as of the end of the census year ending May 31, 1880 was 272,740,00 board feet.

While the map shows that the timber had been removed along Alapaha River in the vicinity of Grand Bay (via the river and the railroad to Brunswick and Savannah) and along the lower Withlacoochee River near Valdosta, lands of the interior had been hardly touched except where cleared for agriculture. The difficulties of cutting and transporting logs to where they could be floated downstream to sawmills prevented extensive commercial operations until the advent of steam power. After the Civil War, however, steam powered logging proliferated, with development of steam skidders, narrow gauge railways and steam powered boats and sawmills. The wave of intense logging that brought down the remaining virgin forests of Georgia during the era 1870-1920 had just begun. The fact that nearly a billion board feet of virgin longleaf pine remained in Berrien, Clinch and Lowndes counties (Table 10 below) indicates that the remaining interior longleaf pine forests of the Grand Bay region that had not been cleared for agriculture were still largely in virgin condition. While the railroad connecting Valdosta with timber markets in Savanna and Brunswick had been completed in 1860, the map shows timber removed along the railway only as far as the Alapaha River, so much virgin longleaf pine would have still remained in the Grand Bay area in 1884.

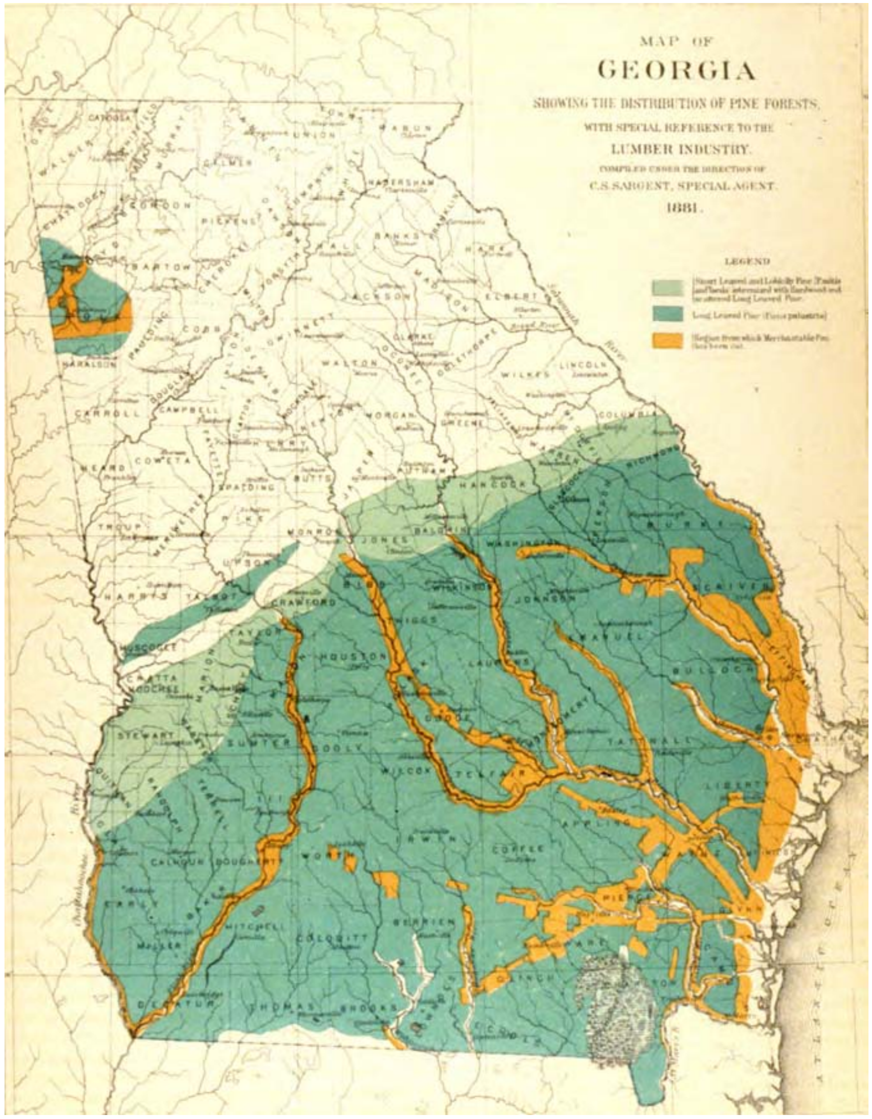

Figure 5. Map of longleaf pine in Georgia (Sargent (1884). Notice the orange band along this route, showing the area where timber had been logged within easy reach of the railroad extended as far as the Alapaha River and large scale commercial logging was poised to enter the Grand Bay region. The Savanna and Gulf railroad (latter the Seaboard Coast Line and CSX) when extended in 1860 to Valdosta passed by the turpentine still at Indianola.

Sargent reported that the principal lumber mills in Georgia were located at Savannah, Brunswick, Darien and St. Marys—all on the Atlantic coast—and that logs were floated from the interior downstream to the mills there. Steam powered sawmills had only recently been developed, mostly since the end of the Civil War, however, and Sargent noted that they were springing up along the railroads, which served as routes of transportation of the milled lumber to Atlantic coastal ports. Large scale turpentining was also on its way to the Grand Bay region.

In 1884 Sargent noted that "the boxed areas include nearly all the regions from which any pine has been removed, and extend beyond them in all directions into the uncut forests and along rivers and railroads." "The merchantable pine in the immediate vicinity of the principal streams and along the lines of railroad

has been removed, and serious damage has been inflicted upon the pine forests of the state by the reckless manufacture of naval stores [turpentine and rosin]." He also noted, however, that vast areas of pine still remained.

Table 10 below summarizes Sargent's estimate of nearly a billion board feet of longleaf pine timber remaining in the vicinity of Grand Bay as of May 31, 1880 (Sargent 1884, p. 520). There was no estimate for the amount of slash or other pines.

LONGLEAF PINE REMAINING in 1880	
County	**Feet, board measure**
Berrien	410,000,000
Clinch	350,000,000
Lanier	county not created until 1921 (from Berrien, Lowndes & Clinch)
Lowndes	236,000,000
TOTAL	**996,000,000**

Condition of longleaf pine remaining today. It is hard to conceive today of nearly a billion board feet of longleaf pine in the three counties around Grand Bay, so thoroughly has it been extirpated from most of the uplands. Of all the longleaf pine states, Georgia is particularly vulnerable to loss of its remaining longleaf pine habitat because only a small percentage is on public lands (Outcalt and Sheffield 1996), so protection and restoration of any remnant longleaf pine communities is increasingly important to the natural heritage of the state. In the 10 years from 1985-1995 the amount of longleaf pine declined 22%. Only on public lands has the amount remained fairly stable. The amount on forest industry lands declined 50% in Georgia during that time. The largest amount of unprotected longleaf pine remaining is on lands of private nonindustrial landowners including non-forestry corporations, and harvest levels are expected to increase because of increasing prices for longleaf. 75% of all remaining longleaf is found in stands of < 100 acres. 25-35% of the longleaf pine remaining in Georgia occurs in stands of 20 acres or less, 45-60% is in stands < 50 a., and Georgia has considerable land in the nonstocked category—cutover lands that have regenerated poorly (Outcalt and Sheffield 1996) . Georgia has the lowest percent of longleaf pine in public ownership. Few longleaf stands on hydric savanna soils remain in any state (Outcalt and Sheffield 1996), a reason why restoration of fire on the Alapaha, Leefield, Pelham, Mascotte and Olustee wet savanna soils is important at Grand Bay. The wet savannas are the smallest of the remaining longleaf community types and represent the most species rich sites, with the most rare species in the South. Those most in need of restoration are highlighted in red in Table 25 below and in the vegetation descriptions that follow it.

Turpentine production, logging, agriculture and the decline of longleaf. On many areas of the Atlantic coast turpentine production was interrupted by WWII and was not resumed afterward, the largest percentage of longleaf pine having been exhausted and the remainder logged for military construction materials during the war. On the Gulf Coast, however, turpentining resumed and was continued into the 1960's in the Grand Bay region (pers. comm., local forester). One tree at the Moody AFB sewage treatment plant when cored appeared to have been cat-faced for turpentine as late as 1956. I interviewed Mr. O'Brien (of O'Brien Road), 74 years old, who still had a pile of tin Herty cups and had worked in turpentining as a teenager in the 1940's). Figure 7 below shows a turpentine still at Indianola in Lowndes County only about 5 miles south of Grand Bay. Indianola was a small settlement which sprang up along the Atlantic Coast Line Railroad on U.S. 84 and is shown on the 1917 soil map of Lowndes County. The last turpentine produced from the Grand Bay region likely went to this still and was shipped from Savannah or Brunswick.

Figure 6. Boxing longleaf pine for turpentine, Lowndes County.

Figure 7. Turpentine still at Indianola, Lowndes County in the early 20th century. Indianola is on the CSX railroad line (formerly Atlantic Coast Line) which has branches to both Brunswick and Savannah, and turpentine and rosin produced here probably went by the railroad to one or both ports, the two principal centers for export of naval stores products and lumber. The still was just southeast of the Grand Bay area. Small lumber mills were also common along railroad routes (Sargent 1884).

Figure 8. The rosin yards at Savannah, Georgia in 1893. Every barrel of distilled turpentine contained the entire life's production of 33 virgin longleaf pine trees, with a byproduct of 4 barrels of rosin. Net profit per tree was about 20 cents (Mohr 1893). Photo courtesy of U.S. National Archives. Some of these barrels of turpentine and rosin could have come from the Indianola still near Grand Bay if it were in operation by this date.

Figure 9. One of several large longleaf pines on the grounds of the Moody AFB sewage treatment plant. All had been boxed for turpentine. This tree has completed healing over an old "catface" scar from turpentining carried out around 1956. These were nearly the only longleaf seen on Tifton and other well drained upland soils of the region, once dominated by this species in the original landscape.

TABLE 11. CHRONOLOGY OF EVENTS IN THE DECLINE OF THE LONGLEAF PINE ECOSYSTEM IN GEORGIA

1607-1732	Land clearing, hogs and other feral livestock introduced into the woods.
1714	Introduction of water-powered sawmills. Beginning of small-scale sawtimber removal from lands along waterways.
1750	Feral hogs reach saturation density on open range in much of the South, eliminating much longleaf seedling establishment in populated regions. This would not have occurred until 1840-1850 in the Grand Bay region. There were 20,349 hogs reported in Lowndes County by 1840, only 20 years after it was opened for settlement (6th U.S. Census 1841).
1815	First steamboat in the South; ten in use in South Carolina by 1826. Introduction of steam power marks the beginning of the Industrial Revolution in the South.
1833	Construction of first railroad in the U.S., between Charleston and Hamburg, South Carolina. Ties and first rails were longleaf pine heartwood.
1834	Introduction of the copper still for distillation of turpentine. Beginning of era of massive turpentining operations.
1840	First commercial production of naval stores in South Carolina, from Horry, Marlborough and Richland Counties. Longleaf pine finally decimated in Virginia after 200 years of small scale naval stores production as a cottage industry. Only a scant 153 barrels of tar, pitch, rosin and turpentine reported for all of Georgia.
1850	Turpentine production peaks in North Carolina, focus begins to spread south as forests are exhausted.
1860	Feral hogs reach saturation density on open range in most of the range of longleaf pine.
1850-1870	Rapid proliferation of steam technology for logging railroads, steam skidders, steam-powered sawmills. Beginning of the naval stores era in Georgia.
1880-1890	Beginning of standardization of railroad track sizes and linking of formerly isolated railroad lines, making overland transport of lumber practicable.
1870-1920	Massive logging, powered by steam technology. Most remaining virgin forests in Georgia logged.
1890's	Huge quantities of naval stores shipped down the Savannah River and other navigable streams and by railroads from interioir counties such as Lowndes which had been reached by rail by 1860 .
1880-1930	Stock laws and/or fence laws passed in most of the range of longleaf pine. Last major stand regeneration occurs in many areas, in the years between the end of open range grazing (which suppressed longleaf reproduction) and the beginning of modern fire suppression.
1927-1950	Most of the range of longleaf in Georgia comes under effective fire suppression. Dense second-growth forest succession begins to replace diversity of savanna, woodland and open fire-maintained forests.
1928	Georgia leads the nation in production of turpentine and rosin. Decline of longleaf pine intensifies.
1929-present	Escalating conversion of woodlands to pine plantation, especially loblolly pine and slash pine.
1943	After much debate, U.S. Forest Service gives approval to use of fire in managing woodlands. Many areas on public and private lands, however, are excluded from fire.
1962-2005	Tall Timbers Fire Ecology Conferences foster growing appreciation of role of fire as a forestry tool and in maintaining natural ecosystems.

Records of turpentine leases in county courthouse deed books give a picture of the extent of longleaf pine and the naval stores industry in the original pine forests. On August 6, 1903, James Banks leased to G.V. Gress 680 acres in Lots 178 (all of its 490 acres) and 190 acres of Lot 267 on its the west side. Lot 178

included part of Grand Bay and the well-drained uplands on its west side to the vicinity of Oxbottom Road. Lot 267 lies to the southeast of Grand Bay. This was a 15 year timber lease to run from 1903-1918 "for saw mill purposes or turpentine purposes as aforesaid with all the rights and privileges of cutting and boxing the trees on said land and the constructing of all necessary trams over said lands for the purpose of conveying the timber or crude stuff to the mills or still…" Lowndes County Deed Record Book AA p. 25. The existence of commercial quantities of turpentine helps establish the dominance of longleaf pine on uplands of the natural area.

Turpentining came relatively late to south Georgia. In 1850 North Carolina was the worlds leading supplier of turpentine and other naval stores but the "turpentine orchards" of that state were largely exhausted in the next three decades and the industry moved south to South Carolina where it peaked in the late 19th and early 20th century. Much of the production shown in Figure 8 of the Savannah Rosin Yards in 1893 came down the Savannah River from the upcountry of South Carolina and adjacent Georgia. Railroads tributary to the two main ports for export of naval stores. Savannah and Brunswick began bringing in turpentine from south Georgia in the last three decades of the 19th century and by 1928 Georgia was the largest turpentine producer in the U.S. (Coleman 1991).

Agriculture. Although the lands of Lowndes and Lanier County were only opened to settlement with the land lottery of 1820-1821, much land had been cleared by the Civil War. By the late 1800's most of the best agricultural soils such as the Tipton and Fuquay had been cleared (Figure 10).

Figure 10. Agricultural land on Lowndes County around the turn of the century. Wooded land on the distant left is probably wetland, unsuitable for farming. The long vista in center where no tree line is visible indicates the vast extent of conversion of former longleaf pine lands to agriculture.

HYDROLOGY

Carolina bays and lime sink topography. The most conspicuous geological features are the Carolina bays and lime sink depressions of all sizes and depths that can be seen dotting the landscape on aerial photos. These range in degree of development from the conspicuous oval of Banks Lake to very shallow and poorly defined depressions. The presence of lime sink features does not necessarily imply high pH near the surface; the calcareous strata may lie at some depth and depressions may result from solution and transportation of calcium with subsurface water movement, allowing the land above to sag. The process may take tens of thousands or hundreds of thousands of years. A sample was taken of soft, light grey rock dredged up from a from a deep ditch cut into the west side of Old Field Bay. It had the appearance of marl but when tested only had a pH of 4.7. It is possible that it was originally marl but had become acidified by contact with organic acids leaching down from the swamp and the adjacent acidic pinelands.

There are no Alfisols—high pH soils—in the area and all soils of the natural area are described as medium to very strongly acid. On the Berrien-Lanier soil map one odd soil is the Istokpoga, which in the Grand Bay area represents an artifact of flooding. Milltown Bay is mapped as this type and the soil description says that it is underlain by limestone. The soil itself, however, is characterized as very strongly acid so any marl must lie at some depth.

Regions underlain by limestone develop depressions of all sizes on the surface. Depths range from barely perceptible to meters deep as at Banks Lake. Vegetation varies accordingly from pine savannas where the depression is so shallow that it offers no barrier to the passage of fire, to those so deep that they become permanent ponds and lakes. All of this develops continuously from solution and transport of subsurface lime. Bay development on the surface, with formation of the classic oval shape and sand rim depends upon wind and water action over log periods of time. Bays of all sizes and all stages of development can be seen at Grand Bay/Banks Lake, the largest such complex in Georgia with exception of the Okefenokee.

Banks Lake has all the classic features of a fully expressed Carolina Bay. It has a sandy rim and an oval shape elongated slightly from northwest to southeast and perfect oval development is interrupted only by the bluff of high land on the northwest side. The sandy rim has been mostly inundated by the impoundment but shows up on aerial photos as a ring of pond cypress which became established in shallow water or during periods of low water after impounding. The original vegetation of the rim was likely longleaf pine on the southeast side where it adjoined fire-exposed savannas and mixed longleaf-slash and possibly some hardwood hammock on the partially fire sheltered west side.

Past Water Levels in Banks Lake

There is considerable evidence to indicate that the maximum level of water in Banks Lake from its inception around 1830 to World War II was always at least one foot lower than at present, no matter how high the dam was raised at Mill Creek. Evidence on the earliest historical maps suggests that the original mill pond built by Joshua Lee was much shallower than at present, at least before 1848.

Water levels prior to WWII. The full-pool water level in Old Field Bay at 191.6 feet (Hon 1995) is linked with and nearly the same as in Banks Lake and its water level and that in Shiner Pond to the south are controlled by the dam at Banks Lake dam at Mill Creek. With the current water level, water is pooled at Shiner Pond, which is apparently the deepest point on the south end of Old Field Bay and the location of the natural southward-draining creek channel indicated on historic survey maps. Without the Moody AFB crash trail dike, with its water control structures along Shiner Pond Road, the dam at Banks Lake before WWII could never have been as high as at present because excess water would have just spilled out of the system to the south into Moody Bay and Grand Bay Creek. The 1917 soil map shows that the Shiner Pond dike flooded areas of previously exposed mineral soil in its vicinity (see legend for 1917 soil map below).

Water level in Banks Lake would have had to be at least a foot lower at that time, and probably more depending upon the drop from the Shiner Pond dike at full pool to the bottom of the original natural drain (not the swamp floor) below. No mill keeper could never have been able to raise the level as high as it is now no matter how high he built the dam on Mill Creek.

Full pool elevation in Old Field Bay (191.0 ft) and in Banks Lake, 191.6 feet, is about 4.4 feet higher than full pool elevation downstream from Shiner Pond Road, which is 186.6 feet in Moody Bay, Rat Bay and Moccasin Bay Wildlife Management Units (Hon 1995). This does not mean that there is a 4 foot drop immediately on the south side of the Shiner Pond Road dike, however, because Moody Bay slopes downstream to where the elevations were taken.
Data needed: 1) the difference between full pool elevation of Shiner pond (191.0 feet) and the bottom of the deepest <u>natural</u> channel just below the dike. This would provide an estimate of the lowest level the Mill Creek dam could have been to pool the maximum amount of water. 2) A good estimate of the depth to which the Shiner Pond dike raised the water level around 1941 could be obtained using a boat to take water depth measurements over the lowest mineral soil (labeled Pf on the 1917 map, just north of the Shiner pond dike) that was flooded by the dike. 3) To get precisely the maximum height of water that the Mill Creek dam could have ever pooled without the dike at Shiner Pond, the best way might be to draw down the water level in Banks Lake a meter or two in order to expose the divide between the western drainage of Old Field Bay into Moody Bay and the eastern drainage into Banks Lake and then arrange a LIDAR flight to get a precise topographic map. Contour intervals of less than one foot are possible with LIDAR. This should give the maximum height of water level possible in Banks Lake before construction of the dike around 1941.

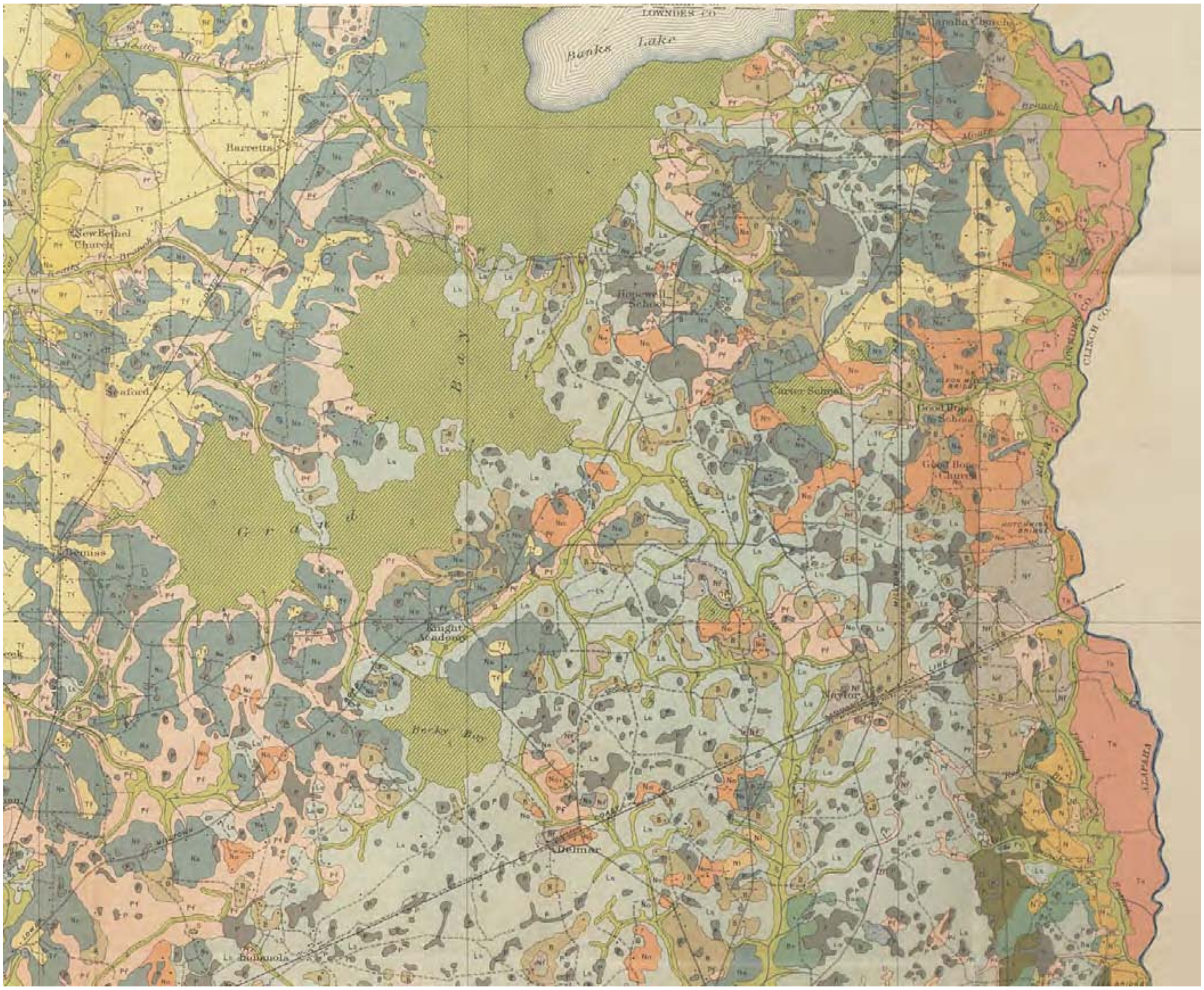

Figure 11. A portion of the 1917 soil map of Grand Bay and Banks Lake. The site of the Indianola turpentine still can be seen due south of the Grand Bay Education Center near where the railroad exists the map at bottom. In comparing this map with the current soil map (Shiner Pond is now in Lanier) which was published in 1973 on aerial photography flown a few years before the publication date) the upper lobe of Peters Bay seems to have had less water and more soil in 1917, and there was definitely some mineral soil that was flooded by the Shiner Pond Road dike (see detail below). The open water labeled Banks Lake at the northeastern boundary of the map is all in Old Field Bay. The Banks Lake Carolina bay is just off the map to the north in what was then still Berrien County.

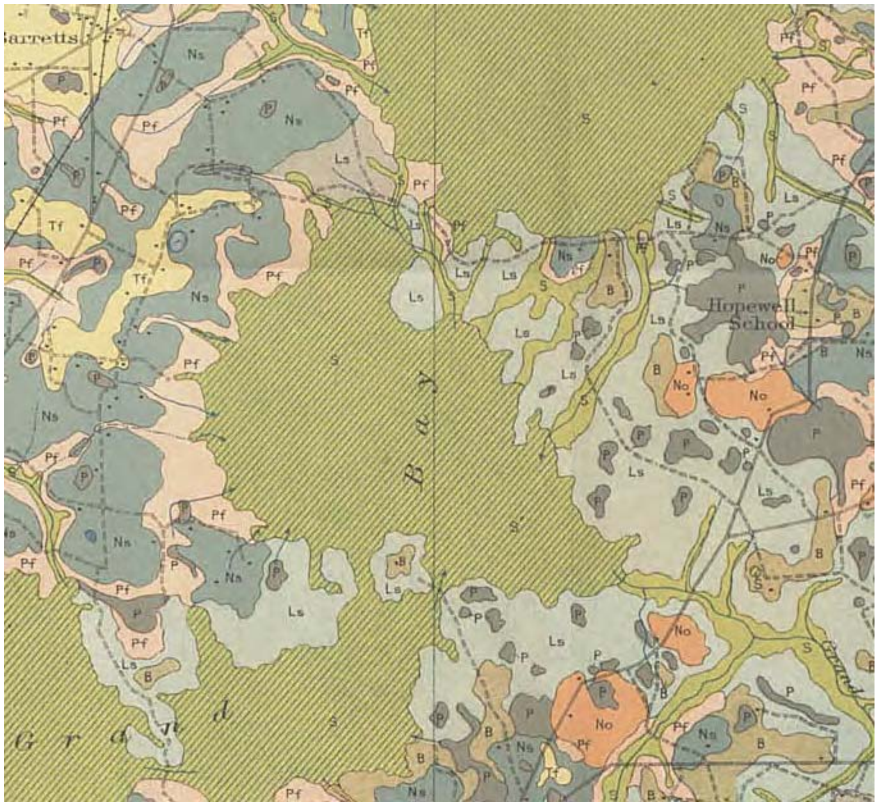

Figure 12. Detail of the Shiner Pond area before pond construction. The road that passes between Moody Bay (where the word “Bay” appears) and Old Field Bay to the north is now the Shiner Pond Dike. The bodies of mineral soil along it from upper left to lower right (Ls, Pf, Ls (tiny), Pf (tiny), Ls (large, rounded)) are all smaller on the modern soil map than in 1917 indicating post-impoundment flooding. The first Pf soil pedon has been completely inundated by Shiner Pond and the round body of Ls soil below it and been reduced in size suggesting some increase in water level in Moody Bay at this point downstream from the pond dike.

Water levels between 1847 and WWII. Evidence on the earliest historical maps suggests that the original mill pond built by Joshua Lee was much shallower than at present. Wetland and streams on the 1820 survey map are crudely drawn (Figure 4). The Bonner map of 1847 (Figure 1), however, shows the whole wetland complex, including Mill Creek, the divide between Banks Lake and the Grand Bay Creek headwaters, and four branches in the headwaters of Grand Bay Creek, all with considerable accuracy and in agreement with the pattern seen in the bottom transects below. This shows that someone had visited and mapped the area sometime between 1820 and 1847, the year before Joshua Lee sold the mill to William Lastinger. The accuracy of the drainage patterns suggests that they were not flooded prior to 1847 to the depth they were by the time of the 1917 soil survey where the patterns were obscured by flooding. Lastinger or a later mill operator raised the pond level to the 1917 level of inundation. The extent of the drainage patterns and the fact that the divide was exposed between Banks Lake/Peters Bay and the headwaters of Grand Bay Creek in western Old Field Bay and along the drains in the western scarp suggests that the original mill dam must have been at least a meter lower than at present. This is highly plausible considering that Lee, attempting to build a major mill dam in remote, virgin country would have limited resources. A relatively low dam would have impounded many acres in the Banks Lake bottomland, sufficient for milling (many historical mill ponds were less than 10 acres). The greater the amount of water available, however, the longer a mill can be kept running during dry periods, so it would make sense for later owners to eventually raise the dam to the maximum of water that it could hold before the excess spilled over to the south into Grand Bay Creek.

WATER AND PEAT DEPTH TRANSECTS

In an attempt to reconstruct the original drainage patterns and now flooded bottomland forest and other plant communities of the Milltown Bay-Banks Lake-Old Field Bay-Grand Bay complex, several transects were run. The transects were done over a five day period. Water levels were checked at the beginning and end of the period at the Banks Lake spillway and at the Grand Bay berm with its three water control structures. The same amount of water was flowing over the structures (4 inches at Banks Lake weir during the measurement period and a mean of 4 inches for the three pipes at the outfall into Grand Bay Creek on the date of measurements there on March 10, 2006), so relative water levels in each system did not change during the measurements. There was no rain during the measurement period.

Transects were done of Milltown Bay, Banks Lake, Old Field Bay and Grand Bay. Water depth, peat or muck thickness, and texture of underlying mineral substrate were determined using fiberglass rods. Depths for all four areas were determined at a time when Banks Lake was full her so that there should be little difference from place to place within the Grand Bay system resulting from change in depth related to rain or drought. The same amount of water, about 4 inches, was flowing over the top of the weir from Banks Lake into Mill Creek on SR 122 on the days it was sampled.

The peat rods, about 1.1 meter long, were calibrated with marks at 10 cm intervals and intervening intervals were measured in centimeters with a ruler. The rods are those used for chimney cleaning brushes and can be screwed together in as many sections as needed to reach the bottom. First, depth of water, from the surface to initial contact with peat or muck on the bottom was recorded. Then thickness of any peat, muck or ooze was recorded. Finally, texture of underlying substrate was recorded. This can be determined with practice as follows:

Substrate texture codes:

s Sand – coarse vibrations felt when twisting the rods with slight downward pressure
fs Fine sand – distinct vibrations but without the rough feel
ls Loamy sand – less distinct vibrations
sl Sandy loam – only a little grittiness detectable
vfsl Very fine sandy loam – sand grains barely detectable
c Clay – firm contact, no vibration: oily, smooth rotation when downward pressure applied and rod only penetrates a cm or two.
o Ooze – no vibrations and rod can penetrate to some depth, substrate sucks at rod, and extraction may be difficult.

Thickness of floating mats of vegetation, being highly variable in terms of age, density and thickness, and largely artifacts of flooding, was ignored and included within the water column.

A continuous transect (interrupted by several gaps where there were impenetrable mats of floating vegetation) was run from US 221 through Milltown Bay, then Banks Lake, then Old Field Bay to the high shoreline on Ben Strickland's farm. The profiles of several of the wetlands varied from saucer shaped, with a regular bottom, as at Grand Bay, and the west side of Old Field Bay, to irregular, suggesting a surface with eroded drainage patterns and stream channels before flooding, as at Banks Lake, Milltown Bay and the eastern side of Old Field Bay.

Milltown Bay is a Carolina bay that shows less conspicuous development than Banks Lake but has some northwest/southeast elongation and there could be some bay rim development beneath the impounded margins. Darsey Pond, to the east across US 221 has a drain leading east into the Alapaha River bottomland and a shallow slough to the west extending toward Milltown Bay. The Milltown bay bottom

was at a lower elevation and never could have drained east through Darsey Pond. Impounding Banks Lake to a depth of 3 meters completely flooded Milltown Bay up to the edge of US 221. Any increase of water level in Banks Lake would have spilled out via the slough to Darsey Pond, as well as the headwaters of Grand Bay Creek.

Research needed: complete bathymetry of Milltown Bay using 10-20 north-south transects. Alternatively, LIDAR imagery flown when the water is drawn down, to create a 1 foot contour interval map, would allow interpretation of the original nature of the bay. It may have been a wet forest with a linear drain connecting to the inundated portion of Mill Creek (likely, considering the irregular bottom revealed by the eastern transect below) or it is possible that its could have had a flat bottom. perched above the bottom of the original Mill Creek drainage now under Banks Lake, so that there could have been wet graminoid vegetation maintained by fire and/or small beaver impoundments.

3/9/06	**Transect: Milltown Bay, eastern edge toward middle**				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
1	30	40	70	clay	Began W of US 221, 10 m into water from shoreline
2	63	85	148	fs	Nymphaea pool with pond cypress
3	66	60	126	c	Nymphaea pool with pond cypress
4	57	120	177	fs	Nymphaea pool
5	65	45	110	fs	opposite big TAAS group on aerials
6	67	30	97	fs	past TAAS cluster (soil map photos)
7	45	75	120	fs	in floating vegetation mats (not able to go farther with canoe)

Table 12. Transect from US 221 into Milltown Bay. Note irregular bottom and lack of ooze that might indicate any preexisting pond.

3/13/06	**Transect: Western rim of Milltown Bay into Banks Lake**.				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
8	38	53	91	lfs	Dense TAAS on submerged Carolina bay sand rim between Milltown Bay and Banks Lake
9	48	50	98	lfs	TAAS/ITEAVIR/water
10	62	33	95	lfs	TAAS/ITEAVIR/water
11	68	54	122	lfs	TAAS/DECOVER
12	93	47	140	fsl	TAAS/NYOD
13	133	38	171	fsl	TAAS/water hyacinth
14	200	5	205	fsl	Open water
15	235	15	250	fsl	Open water
16	238	52	290	o	Open water
17	253	39	292	o	Open water
18	272	38+ ooze	310	o	Open water
19	274	50+ ooze	324	o	Open water

Table 13. Transect beginning at eastern end of Banks Lake, westward into center of lake. Points 16-19 had gummy ooze and bottom was not reached on points 18 and 19 because it was only possible to penetrate the thick ooze for a certain distance. Deposition of fine ooze could possibly have taken thousands of years. Pockets of deep ooze were encountered in two places on the transect of Banks Lake (see tables below). Considering that the ooze begins about at the level of the bottom of Mill Creek (3 meters below current water level) and extends to a depth greater than 3 meters strongly suggests two small, pre-existing pools, possibly beaver ponds, in the original bottom. TAAS = *Taxodium ascendens* (pond cypress), NYOD = *Nymphaea odorata* (fragrant water lily), ITEAVIR = *Itea virginiana* (Virginia willow), DECOVER = *Decodon veticillatus* (water willow)
Research needed: Have ^{14}C dating done on any carbon obtainable from ooze deposits. Existence of this feature should be reported to palynologists as a possible site for future work.

3/11/06	**Transect: Banks Lake, east central to western side of Peters Bay**				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
20	230	97	327	c	
21	230	108	338	o	ooze deposit suggests former pond or beaver pond. Open water
22	215	71	286	o	ooze. Open water
23	164	59	223	fsl	near osprey nest in cypress. Open water
24	176	54	230	fsl	just outside Peters Bay. Open water
25	180	50	230	fsl	Channel into Peters bay. Open water
26	62	38	100	c	TAAS/Utricularia inflata
27	68	44	112	fsl	TAAS/Utricularia
28	60	45	105	fs	TAAS/Decodon-impenetrable mats

Table 14 is a continuation of the transect across Banks Lake into Peters Bay.

Alligator Run (Eagle Nest Run) cuts through the submerged western Carolina bay sand rim of Banks Lake. It appears to be the outlet for Alligator Run, a small drain originating northwest of and draining Berryhill Pond on the uplands north of SR 122 before flowing south under the highway into the northeastern corner of Old Field Bay and thence east through a gap eroded through the now submerged sand rim, into Banks Lake. This creek drains about five or six square miles of uplands and is shown on the 1820 survey where it is called Allacooche creek on the surveyor's notes.
Research Needed: Further transects are needed to determine whether Alligator Run was the only original drain at this point, with a divide separating it from Old Field Bay to the west, or does Eagle Nest Run (a more recent name) include one or more western or southwestern branches that originally, along with Alligator Run, drained this portion of Old Field Bay into Banks Lake.

Banks Lake Western Sand Rim. This short transect was run from the open water of Banks Lake beginning between SR 122 and the mouth of Eagle Nest Run, west to the top of the submerged sand rim that divides Banks Lake from Old Field Bay.

	Transcript: Banks Lake bottom, west to top of northern segment of inundated Carolina bay sand rim				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
1	195	102	297	vfsl	100 m offshore from the TAAS stand above the buried sand rim on north side of Eagle Nest Run
2	27	51	78	fsl	just inside TAAS stand
3	11	48	59	fs	TAAS/CLAL/Lemna sp.
4	14	44	58	s	same

Table 15. Short transect from the bottom of Banks Lake about 100 meters offshore between SR 122 and the mouth of Eagle Nest Run, west onto top of submerged Banks Lake Carolina bay sand rim. Note the sharp rise from the lake bottom to the top of the sand rim. Points 3 and 4 lie on the flat top of the buried rim, where it lies only about 23 inches below water level (actually 19 inches below full pool water level since 4 inches were coming over the top of the weir). Vegetatation abbreviations: TAAS – *Taxodium ascendens,* CLAL – *Clethra alnifolia*

Figure 13. Pond cypress stand on top of submerged Carolina bay sand rim on north side of the mouth of Eagle Nest Run (the mouth of the original Alligator Run). There is about 18 inches of root mass and muck between the water surface and the top of the sand substrate. Note an old pine heartwood stump in the lower right at the foot of a cypress trunk. Many of the cypress had old healed fire scars and most of the pine stumps had char from one or more past fires that occurred most likely when the lake level was low during droughts. This particular point is close enough to the former longleaf pine uplands along SR 122 to have been influenced by fire in the pre-impoundment landscape.

The pine stumps in Figure 13 might predate the circa 1835 impounding and probably represent slash pine with some longleaf toward the northern end. Alternatively the site, while wet, may well have been dry enough for slash pine reproduction for the century before the Shiner Pond dike allowed raising the water level to its current height. The younger cypress on this rim may date to the same event.
Research needed: The question could be resolved by studying slices of a few of the pine stumps and cores of the cypress.

Perhaps contrary to the TAI (1994) report, there seem to be at least four cohorts of pond cypress in the natural area. First are the few old pre-impoundment trees, 200 or more years old, that have continued to adapted through the apparent three incremental stages of flooding of Banks Lake (~1835, 1848? and WWII) (see Figure 17 below). These old trees can be found in the lake itself and there may be a few left in peripheral sloughs. Second are the older, multi-aged trees all around the wetland margins and shallows. These have formed by ongoing germination, especially when mud is exposed during droughts, over the 170 year history of the mill pond. Third are the young, apparently even-aged, post WWII stands such as those in Figure 13 above that may be related to water level increase after construction of the Shiner Road Dike. Fourth and youngest are the all-aged stands developing on floating vegetation mats in the impoundments. With no other management it seems likely that the long term outlook for all of the areas, including the Grand Bay Education Center wetlands, with exception of Banks Lake, will be succession to closed forest of pond cypress and swamp black gum, facilitated by germination in the floating mats and formation of a peaty substrate tied together with tree roots.
Research needed: More detailed and broader core and tree ring studies than those done in the TAI report.

The 1820 survey of District 10 recorded "L.W.", the surveyor's abbreviation for lightwood or lightwood tree (longleaf pine) at a point on the northern segment of the rim where the photo for Figure 13 was taken. Considering the 3.1 meter height of the modern water level at top of the Banks Lake weir, the top of this sand rim, now flooded to a depth of 60 cm, would have stood high and dry at about 2.5 meters above the channel of Mill Creek in the former bottomland. The northern end of the rim was attached to fire-exposed former longleaf pine uplands but became increasingly fire sheltered toward the south by moist bottomlands and small swamps on both sides. Original vegetation likely graded from longleaf pine at the northern end, into slash pine and possibly some hardwood hammock on the isolated middle segment.

	Transect: **Mouth of Eagle Nest Run** across breach in sand rim from isolated middle segment of rim to the northern segment that extends to SR 122				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
1	32	43	75	fs	recent, (5-10 year old?) fire char on TAAS (perhaps from aerial ignition)
2	24	48	72	fs	TAAS/shrubs
3	220	22	242	fs	channel of Eagle Nest Run
4	85	58	143	fs	open water
5	63	77	140	fs	open water
6	112	38	150	fsl	grassy mats under TAAS
7	14	44	58	s	same as point 4 in table above

Table 16. Transect across the mouth of Eagle Nest Run (mouth of the original Alligator Run) from the middle segment of the (inundated) western sand rim of Banks Lake from south to north. This segment was isolated from the others in the original landscape by two breaches in the sand rim, the one connecting Banks Lake to Peters Bay to the south of the middle rim segment and the other being the mouth of Eagle Nest Run on the north. Impoundment led to replacement of the original pines by the even-aged stand of pond cypress now present.

3/11/06	Transect: **across mouth of drain leading from Peters Bay into Banks Lake**				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
1	65	24	89	fsl	TAAS/water
2	65	43	108	vfsl	
3	100	30	130	vfsl	NYOD-water hyacinth
4	152	15	167	lfs	
5	220	43	263	fs	channel of drain from Peters Bay
6	175	48	223	vfsl	
7	106	66	172	fsl	
8	68	39	107	vfsl	
9	61	40	101	fs	
10	32	43	75	fs	same as point 1 in table above

Table 17. Transect across the channel connecting Peters Bay and Banks Lake. This represents the southwestern breach in the Banks Lake Sand rim. The transect begins on the southern segment of the rim and crosses the channel to the isolated middle segment mentioned above. Several factors suggest that Peters Bay drained north and east through this gap into Banks Lake in the original wetlands. The channel here was 2.6 meters at its deepest point while the bottom of Banks Lake is over 3 meters in several points just to the east. In Peters Bay, open water decreases and trees close in to the west of this transect indicating shallower water and the bottom slopes towards Banks Lake (see Table 14 above). In addition, historical maps show the main run of Mill Creek originating south of this gap in the vicinity of Peters Bay (Bonner 1847).

Old Field Bay. Most place names have some basis in historical fact so it seems likely that this large bay got its name because there was some farming some time in the past, at least on the peripheral flats to the north and west which have exposed patches of mineral soil even today despite the 3 meter impoundment.

Moody AFB is on the divide between Old Field Bay and the Cat Creek drainage to the west. To the northwest, Ray City is on the Cat Creek side of the divide. There are number of minor drains northeast of Barretts around the circumference described by SR 122 around Old Field Bay. Lands to the north of SR 122 drain south into Old Field Bay. On the west side one drain originates north of Moody AFB near SR 125 at Barretts and drains east and then southeast through Old Field Bay, apparently into Shiner Pond. *Future research needed*: was there indeed a divide between this drain and the east side of Old Field Bay in the original landscape? The drainage patterns on historical maps indicate that this was so.)

3/11/06	Transect: **Western side of Old Field Bay to toe of hardwood uplands**				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm)	Substrate Texture	Notes
1	30	134	164	vfsl	NYBI
2	38	122	160	vfsl	NYBI/UTRIINF-Lemna
3	20	46	66	fsl	NYBI/SAURCER-Wolffiella
4	0	45	45	fsl	NYBI/ITVI-LYLU
5	20	30	50	vfsl	NYBI/SPARAME
6	10	70	80	fsl	NYBI
7	0	15	15	fs	NYBI, edge of soil at slope toe

Table 18. Transect of about 1000 meters, from the western interior of Old Field Bay, west to the live oak-pignut hickory-Magnolia forest on its western slope on the Ben Strickland farm. NYBI = *Nyssa biflora* (swamp black gum), UTRIINF = *Utricularia inflata* (bladderwort), SAURCER = *Saururus cernuus* (lizard's tail), ITVI = *Itea virginica* (Virginia willow), LYLU = *Lyonia lucida*, SPARAME – *Sparganium americanum* (bur reed). This transect differs from all others in that the water depth is shallow and the substrate is firm enough for walking. Soils here was likley dry enough for farming in the past.

Grand Bay is highly unique among the diverse assortment of wetlands of the natural area. The firm, predominantly clay substrate indicates that Grand Bay is a true clay-based bay. In contrast to Milltown Bay, Banks Lake and Old Field Bay, its bottom is almost uniformly flat and undissected by former drainage patterns. It lies in a shallow pan perched 7 feet higher than the bottoms of the original Banks Lake bottom and was much more fire exposed in the original landscape.

3/10/06 3/14/06	Transect: **Grand Bay, east to west**				
Sample Point	Water depth (cm)	Bottom peat or muck (cm)	Total flooding depth to original substrate (cm).	Substrate Texture	Notes
1	45	30	75	c	TAAS-NYBI/Eichhornia crassipes 50 m from shoreline
2	70	21	91	c	Pontederia mats
3	55	41	96	c	TAAS/Eichhornia
4	70	39	109	c	Nympaea odorata (NYOD)
5	90	43	133	c	Hydrocotyle-Eleocharis mats
6	90	80	170	c	Andropogon glaucopsis mats
7	90	41	131	fsl	NYOD
8	90	43	133	fsl	NYOD-Brasenia schreberi
9	80	48	128	c	Dulichium arundinaceum mat
10	85	62	147	c	Dulichium arundinaceum mat
11	90	45	135	c	Andropogon
12	55	94	149	c	Decodon verticillatus
13	95	43	138	c	Turing west toward W shore of Grand Bay. NYOD
14	70	60	130	fsl	Begin small TAAS, sphagnum mat
15	80	43	123	fsl	TAAS (to 6 inches dbh/Decodon

16	48	76	124	fsl	NYOD beginning north/south fence line trail.
17	112	37	149	lfs	TAAS/Hydrocotyle-DECOVER
18	56	75	131	lfs	NYOD-Juncus equisetoides
19	31	79	110	c	NYOD-Juncus equisetoides. Turning toward west shoreline cypress stand.
20	32	78	110	c	NYOD-TYLA
21	74	37	111	vfsl	TYLA-NYOD-Ricciocarpus natans (liverwort)
22	0	126	126	vfsl	edge of zone of impenetrable mats between water lilies and western shoreline: Tyla-WOVI-Eleocharis baldwinii-MYCE-CEOC
MEANS	69 cm	56 cm	125 cm		
10 cm excess water subtracted	59 cm	56 cm	115 cm		

Table 19. Transect of Grand Bay beginning from the boat ramp on north side of Grand Bay Creek, east along canoe trail to old north-south fence line west of the center of Grand Bay (see Figure 15), then along fence line south for about 100 meters, then west through water lilies to edge of cypress off western shoreline. All measurements were taken away from the canoe trail and fence lines in order to avoid any effect they may have had on water depth or organic accumulation.

Natural full-pool water surface elevation of Grand Bay. The 200 ft contour rings the bay and a few low islands within it. The 190 ft contour appears about a mile downstream in Grand Bay Creek. The full pool elevation of Grand Bay in fall 2005, with just a trickle of water coming through the three pipes at the berm northeast of the education center on Grand Bay Creek was 191.5 feet, based on water level surveys by Tip Hon. When the current pipes were put in around 1991 the full pool level was 192.2 feet but one 8 inch flashboard riser was removed to address a complaint from a landowner about flooding a low part of his property, reducing the level to 191.5 feet (Hon 2006, pers comm.).

From 191.5 ft. subtract 30 cm (1 ft) impounding measured at the berm near the Education Center in 2006 to get about 190.5 feet maximum full pool elevation of the water surface in Grand Bay in the original situation before impounding. This is without considering that the water in Grand Bay Creek below the berm may have been a few inches lower in the original situation: in fall 2005, when no water was coming through the water control structures, water was still pooled to an unmeasured depth in the swamp below the berm, perhaps related to water impounded by one of the dikes downstream. The 1917 soil map of Lowndes County shows a dirt road passing over the outlet of Grand Bay at the location of the present berm.

Natural bottom elevation of Grand Bay. The full pool water depth (above any organic accumulation on the bottom), measured in March 2006, averaged 59 cm water, plus 56 cm soft organics and former soft A horizon material to firm clayey substrate = 115 cm. Subtracting 30 cm water impounded by the Grand Bay berm gives a mean depth to clayey bottom of 85 cm (33 inches) full pool water depth in nature. From the 191.5 ft current full pool elevation subtract 115 cm (3.8 ft in Table 19 above) water/organic depth to get 187.7 feet average bottom elevation at Grand Bay. The surface of Banks Lake has an elevation of 191 ft at full pool with the deepest parts about 3 meters lower (about 10 feet) giving the bottom of Banks Lake near the former Mill Creek channel at about 181 feet. In contrast, the bottom of Grand Bay averages 6.7 feet higher and is perched above all the other large wetlands in the preserve.

Presettlement aspect and flora of Grand Bay. The above estimate gives an original water/organic matter depth of 115-30 = 85 cm full pool water depth for Grand Bay. This is shallow enough for most of the bay, except for scattered wetter pools, to have been seasonally dry. Similar bays elsewhere are graminoid-dominated but show irregular, concentric zones of vegetation related to multi-year variations in the amount of water retained in the lower areas during the summer dry period. Note also that the 85 cm depth to bottom clay includes the original basal soil-graminoid root layer so actual depth of standing water in the original bay was more likely only around 55-65 cm (22-26 inches) when full.

Consider that the organic layer at bottom of Grand Bay was originally a black A horizon, flooded for parts of the year and drained (but mostly still wet) at drier times. This layer would be expected to have been more compact under the natural flooding regime. With permanent inundation it now stays fully hydrated and has received several decades' addition of soft organic plant remains that otherwise would have partially oxidized during dry weather and burned off along with the grasses and sedges periodically under the natural fire regime. In bays of similar depth elsewhere, summer dehydration compacts this into a blackish organic layer, and the tough root/rhizome mat maintained by an abundant grass-rush-sedge cover makes for a firm substrate that can be easily walked on (by cattle as well as humans). Such areas were eagerly sought out for grazing, as cattle fared better on the wetland forage versus the tough, low-palatability wiregrass of the dry longleaf pine uplands.

There likely would have been a few depressions or gator holes wet enough to sustain true aquatics such as water lilies. Water lily zones are common in the wettest parts of Carolina Bays and lime sink ponds elsewhere. In short, all of the current flora at Grand Bay likely occurred in the original landscape but the true aquatic flora would have been limited to beaver ponds and to the small areas of natural habitat in the bay, while graminoids such as maiden cane, other grasses, rushes and sedges would have been dominant in the middle and outer zones. The 1820 survey showed pines as the only tree species in the middle and central parts of the bay. These would have been slash pine – the only pine able to tolerate the combined flood-fire regime. Abundant pitcher plants and other grass-bog species would have been found in non-flooded but permanently wet boggy areas around the margins. The 1820 surveys show that the Tifton uplands to the west were characterized by classic longleaf pine/wiregrass savannas while the low uplands to the south and east would have supported species-rich moist longleaf pine savannas with a flora similar to the small savanna re-created at the education center. Mixed pine savannas, with longleaf, pond pine and slash, could have been found on the wetter soils, such as the higher phase of the Pelham series and parts of the Mascotte and Alapaha, and in slightly fire sheltered places where fire frequency was a little lower.

Figure 14. Craig's Pond, Savanna River Site, South Carolina pools water during the wet season but is just beyond the range of slash pine. This photo was taken well out into the bay so the scattered swamp black gum around the periphery are hard to see in the distance. The imagination would have to fill in scattered clumps of slash pine to complete the comparison with Grand Bay. While the vegetation in the foreground is dominated by tall species such as wetland Andropogons, there are wetter grass-sedge zones of lower stature. There are pitcher plants and scattered swamp black gum around the margin. Behind a ring of loblolly pine, partly the result of fire suppression, the upland is longleaf pine and wiregrass. The original fire frequency here was about the same as in the contiguous pine lands, about 1-3 years, but the wetland flora persists with longer fire-free intervals, i.e. is not actually dependent upon quite that high a fire frequency. The drier parts of Grand Bay may have looked like this although with scattered slash pine throughout as indicated on the 1820 survey, scattered swamp black gum near the margins, and water lilies and other aquatics in semipermanent pools in the deep parts.

If the water level at Grand Bay were lowered to the original level no soils currently mapped in Lowndes county would be appropriate. Similar soils at Craig's Pond are mapped as:
1) Ogeechee - fine-loamy, siliceous, thermic Typic Ochraquults
2) Rembert - clayey, kaolinitic, thermic Typic Ochraquults
These two soils have clayey textures very similar to those on the bottom of Grand Bay

Grand Bay, unlike Banks Lake or Old Field Bay, has little subsurface topographic variation to suggest a pre-impoundment drainage network. The bay bottom is saucer shaped with a quick drop-off to about a meter around the rim to an almost uniformly flat pan averaging 115 cm in depth. Of the total depth to mineral substrate, which was very firm and well defined, 56 cm was soft. This probably represents the remains of the original, mostly graminoid, root mat on the bottom along with its associated humic material. Allowing for at least 20 cm increase after increasing the water depth, for accumulation of decomposing remains of floating mat vegetation that would not have been present, with any plant debris being periodically burned off in the original situation, that would alter the calculations to 79 cm (31 inches) of water and 36 cm (14 inches) of black, mineral-organic A horizon, a thickness within the range I have seen in similar shallow, seasonally wet, graminoid-dominated bays elsewhere.

The above scenario would have the original Grand Bay a graminoid savanna with three roughly concentric vegetation zones. In the wettest parts, rarely dried out, would be the true aquatic community with floating and emergent species such as fragrant water lily (*Nymphaea odorata*, bladderworts (*Utricularia* spp.) , arrowhead (*Sagittaria graminea*), maidencane (*Panicum hemitomon*), and other aquatic forbs and graminoids—the community now greatly expanded with increased water depth. The community of largest extent would have been the broad band of formerly grazed wet savanna, composed of grasses, rushes and sedges, mostly of the same species now found around the margins and forming the floating mats (*Andropogon* spp., *Carex walteriana* and other spp., *Dulichium arundinaceum*, *Juncus* spp., *Eleocharis equisetoides* and other spp., *Scirpus* spp. and *Rhynchospora* spp., as well as wet savanna forbs such as *Lachnanthes caroliniana*, *Hydrocotyle* spp. and *Xyris* spp. Most woody species, including shrubs and suffrutescent species such as *Decodon verticillatus* would have been excluded from these first two communities by fire. The outermost zones, also with frequent fire but with a shorter flooding regime would have consisted of many of the same graminoids and forbs but with scattered slash pine and swamp black gum, prevented by fire from forming a closed canopy. Less flood tolerant graminoids and forbs would dominate this sunny community, now succeeded to young and increasingly dense pond cypress and swamp black gum thickets. Pitcher plants and a rich diversity of species native to bogs and wet longleaf pine savannas would have formed the shoreline, on moist, boggy soils not subject to more than a few days of surface flooding.

Lack of old heartwood pine stumps or old swamp black gum in all but the peripheral regions (along boardwalk) add support to this interpretation, as do the old fence lines and history of seasonal grazing. For a good parallel see Craig's Pond in Figure 14 above. Annual summer drying would have been typical except in the wettest years. Even with the additional 1 foot of water provided by the dike on Grand Bay Creek, the bay shrinks considerably in very dry years. Tip Hon said that in one such year he was able to walk out to the conspicuous cypress head and rookery that stands between the south side of the canoe trail and the observation tower.

The 1820 survey showed 8 pines within the central regions of Grand Bay indicating that there were few areas deep enough to prevent pine regeneration. There were 6 pines and 3 "bays" (likely swamp black gum) recorded around the periphery.

Figure 15. Old fence corner, water depth about 90 cm (35 inches) and 50 cm (20 inches) organic material to mineral substrate. Fences indicate that much of Grand Bay was seasonally dry enough to support cattle grazing. Grazing indicates an original grass-sedge component. The 1820 survey reported scattered pines even in the central portion of Grand Bay. These were most likely slash pine which is the most tolerant of seasonal flooding of the five pines found in the area. No cypress were noted and no wetland hardwoods such as swamp black gum were reported except around the edges, suggesting that the combination of seasonal flooding alternating with seasonal drying and frequent fire was sufficient to keep out gum, other hardwoods and cypress.

PROVISIONAL HYDROLOGIC SUMMARY AND INTERPRETATION

The following opinions are the simplest conclusions based on the limited data about original drainage patterns obtained from the very sketchy information on the original 1820 land lottery survey, historical maps, existing topographic maps (with 5 or 10 foot contour intervals), data and conversations with Tip Hon about past use of water control structures, examination of current levels of impounding by the weir on SR 122 and the low berm on Grand Bay Creek, and use of soils to determine direction of original flow. In the last case, the wetter soil catenas such as Leefield→Pelham→Johnston establish flow patterns from drier to wetter. In addition the basement wetland soils such as Johnston often originate as narrow sloughs, widening as they go downstream. These patterns can be useful for interpretation of natural water flow. ***Research needed*:** If the opportunity ever arises, such as replacement of the weir on SR 122 or other reason to drain Banks Lake, it would be valuable if at all possible to have a special run of LIDAR imagery flown in order to map the wetland bottoms. To facilitate accurate imagery it would be desirable to allow some time for the vegetation mats to dry out, if not to actually burn them to reveal more of the basal

topography. Alternatively, a bathymetric map of the wetlands could be obtained by running a number of parallel transects similar to those reported herein for measuring water depth, organic matter thickness and substrate composition.

GRAND BAY/BANKS LAKE IMPOUNDMENTS					
Management Impoundment (north to south)	Acres (approx)	Dike Length	Full Pool Elevation (ft above sea level)	Water Depth (& muck, below full pool surface to top of mineral soil)	Elevation of bottom of natural outfall (ft)
1 Banks Lake & Milltown Bay	~700?	300 ft?	191	Up to 3.2 m (Banks L.) Up to 1.7 m (Milltown)	180.8 (Mill Creek at weir)
2 Old Field Bay & Peters Bay	2000	1.5 mi	191.0	Up to 2.6 m	182.4 (channel thru sand rim into Banks Lake)
3 Moody Bay	1051	2.5 mi	186.6	?	?
4 Rat Bay	840	4,000 ft	186.6	?	?
5 Moccasin Bay	210	2,000 ft	186.5	?	?
6 Dudley Bay	250	2,000 ft	186.8	?	?
7 Grand Bay	1353	1,300 ft	191.5	Mean 1.25 m, up to 1.7 m	? (less than190.5)

Table 20. Banks Lake and Grand Bay Wildlife Management Area Impoundments (adapted from Hon 1995). See transects in tables above for more detailed information on water and organic matter depths. Question marks indicate areas still requiring work. Bottom elevations give an indication of how much lower water levels could have been in the original landscape.

Caveat*:* While the following descriptions state drainage patterns as though they are fact, they are only the best interpretations with current information and are subject to change upon better information about the submerged topography of all the wetlands.

Milltown Bay drained west from US 221 into Banks Lake via a run that connected with Mill Creek just upstream (now beneath the lake) from the present day weir on SR 122. Although there is a natural slough there, the near connection with Darsey Pond to the east of US 221 is an artifact of raising the water level in Milltown Bay. The main outlet from Darsey Pond to the Alapaha River was by the drain on its east side.

Banks Lake was a forested bottomland with deeply incised drains leading from Milltown Bay, Alligator Run and Peters Bay, joining to form Mill Creek before leaving the lake at the point on the northeast side where Mill Creek had breached the Carolina bay rim. The forest was of slash pine, swamp black gum and sweet bay with only a few cypress in the wettest parts along the drains. There may have been a few beaver ponds in the vicinity of the lake having a substrate of ooze. These would have formed only a small percentage of the bay floor.

Peters Bay is a small depression between Banks Lake and Old Field Bay that might be considered a separate sink with only partial development toward a Carolina bay. Drainage was apparently to the north via a run through Old Field Bay and into Banks Lake through the southern breach in its western sand rim, to join Mill Creek. One historical map (Bonner 1847) suggests that this was the main run of Mill Creek

Old Field Bay was the first wetland actually called Grand Bay on historical documents and this conspicuous large oval wetland was probably the original “Grand Bay” (Lowndes County Deed Book C, p. 6, 1863). This bay presents the most puzzles of the wetland group. The mouth of the “Eagle Nest Creek” drain, perhaps an artifact of flooding, is actually the drowned mouth of Alligator Creek which drains south

across SR 122 into the northeast corner of Old Field Bay and then curves into the lake. The Mitchell (1879) map shows this drain connecting with or actually being the head of Mill Creek, now submerged.

Several early historical maps show a drainage divide within the bay. The east side, including Alligator Creek and Peters Bay are shown draining into the Banks Lake bottomland as part of the Mill Creek drainage tree. Two breaches in the western side of the Banks Lake Carolina bay rim were delimited with the bottom transects (see tables above), one at the passage of Alligator Creek and one in the drain from Peters Bay. The watershed on the west side of the divide is shown draining south through the present vicinity of Shiner Pond, through the wet swamp on the east side of Moody Bay and into Grand Bay Creek. The original 1820 survey of District 11, albeit sketchy, shows the north end of Old Field Bay as dry land and the south end toward Shiner Pond and Moody Bay as swamp. It also shows a creek entering Old Field Bay from the north of SR 122, flowing though it to the vicinity of Shiner Pond.

The oval shape of the shoreline bordering the high uplands on the west and northwest side of Old Field Bay suggest shoreline carving by wave action at a time when the water level was as high as at present but when open water was present. This could have been as long ago as 10,000 years, immediately post-glacial, 40,000 years during the Wisconsin glacial period, or 80,000 years or more during the Sangamon or older Interglacials before Mill Creek, eroding headward, breached the rim, draining the glacial or integlacial lake. The shallowly inundated sand rim of the Banks Lake Carolina bay also suggests water action to develop the smooth oval shape at some time in the geological past. Given that the Coharrie surface (the plain on which Lakeland and the bays are situated) is believed to be early Pleistocene in age, some of these features have had 1-2 million years to develop, during wetter and drier times. Streams naturally erode headward with time. Water levels in both Banks Lake and Old Field Bay systems likely dropped with relative abruptness when the advancing head of Mills Creek ate through the rim wall at its present location. The pattern of drains in these wetland bottoms would have been initiated by this event and had from 10,000 to perhaps a million years for erosion and a drainage tree to develop before reflooding by the circa 1830 mill dam.

The bottoms of all the large and small depression in the natural area are likely still deepening with ongoing solution and transport of subsurface lime.

The exact shape of the submerged divide between the eastern and southern drainages is yet to be determined as is the location of the southward flowing drain or drains from west-central Old Field Bay through the vicinity of Shiner pond into Grand Bay Creek. A transect of the west side from the Ben Strickland farm (see below) did reveal a shallow slough at the toe of the scarp but it had a firm bottom and the bottomland as a whole slopes gently with water deepening gradually toward the center.

Another mystery, visible on aerial photos, is a line of cypress connecting the uplands at SR 122 just west of the Alligator Creek drainage and running almost straight south to the vicinity of Lightsey Hammock. The transects below showed that stands of pond cypress represent shallower water than treeless openings. Presumably this conspicuous linear cypress stand follows a now submerged topographic feature. It is so straight that one is led to speculate that it could represent a low, hand-built causeway leading from the high ground on the north side of Old Field Bay to the uplands beginning on the south side at Lightsey Hammock. There is a roadbed there leading to a small boat launch where the road ends on the southern edge of the Peters Bay swamp but the age of the roadbed is not known. Past increases in water levels could have led to inundation of such a feature. Alternatively the linear feature could be a poorly developed eastern rim of Old Field Bay, separating it from Peters Bay.

Before impounding, most of Old Field Bay would have been forest and some of it on low flats on the north and northwest side could have been farmed. Large areas of this quadrant still have areas of mineral soils above the wet surface or within less than a meter of the surface which means they would have been two to three meters above the bottom of the original Mill Creek drainage, easily dry enough to farm.

Moody Bay drained east into Grand Bay Creek via two or three drains visible on color infrared aerial photography. The southernmost flows southeast into the arm of Grand Bay Creek downstream and east of the Grand Bay berm. There is a small wet area near the center of Moody Bay that drains east into this same arm on the west side of Dudley's Hammock, and the third and major branch is the drain that is impounded by Shiner Pond.

Shiner Pond shows a gradient from shallow on its northwestern end to deep open water at the dike and road. The gradient continues to shallow to the northwest onto wet mineral soil flats with loblolly pine, sweet bay and other hardwoods near the northwestern curve of Old Field Bay. A drain from the highlands to the west is conspicuous on aerial photos and it likely joined one or more small drains from the north in the vicinity of the pond. The dike for Shiner Pond prevents water backed up into it from the Banks Lake impoundment from spilling over into the Grand Bay drainage. Historical maps and the 1917 soil survey map suggest that Shiner Pond is an impoundment on what was the original headwater drain of Grand Bay Creek, as was first suggested on the original 1820 survey.

Grand Bay, in its presettlement condition, may be best interpreted as an open, graminoid savanna, intermittently flooded, with the center pan kept free of trees other than slash pine by the combined regimes of fire and flooding. Descriptions of similar communities in Carolina bays can be found in the historical literature. These open grass-sedge communities with fluctuating water levels could not be farmed but were eagerly sought after for grazing (see William Bartram's description of Alachua Savanna in Florida). Mills (1826) described an area of similar topography and fire regime in Barnwell County, South Carolina as "…a beautiful sheet of clear water near Springtown surrounded on all side by high pine land" Extensive forests of the finest pine timber cover this whole country in the high lands." The agriculturist Edmund Ruffin in 1843 described the same or similar wet savanna in Barnwell County: "Found no indications of calcareous earth by the way, except the existence of some large ponds...." [implying lime sink depressions]. "One pond which we passed today, is some 40 acres in size, & very shallow. It was formerly dry land, except in very wet spells, & was thence called a 'savanna', & was used as a battalion parade ground…." (Ruffin 1843 p. 239).

For a model of the wet margins of the bay see the frequently burned oval savannas in Apalachicola National Forest where slash pine is confined to a narrow transitional band between the flat, treeless, wet savanna bottom and the adjacent longleaf pine savannas only inches higher above the water table. The turpentine tree along the boardwalk could have been either longleaf or slash pine as both were used for naval stores production in the region.

Variations in beaver activity could have been influential in causing fluctuations in water depth in the various units of the system but a dynamic balance of their numbers with those of alligators would likely have prevented their having more than minor local effects. Most beaver ponds would likely have been small impoundments on the numerous small drains from the uplands tributary to the large wetlands below where they would have been relatively safe from predation. Any beaver impoundments in the low lands that could have created sizeable impoundments, however, should have been short-lived because they would have quickly attracted alligators.

PRESETTLEMENT FIRE REGIMES

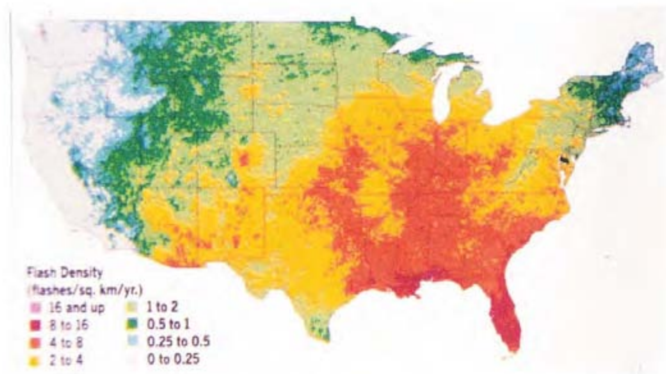

Figure __. Lightning strike density of the Grand Bay vicinity is in the region of the Gulf Coast and south Atlantic interior that receives from 4 to 16 strikes per square kilometer per year, nearly the highest in the country. This would have provided a high ignition frequency even without the use of fire by Native Americans.

METHODS – MAPPING HISTORICAL FIRE FREQUENCY

Assumptions and assertions: The following principles are based on work elsewhere (Frost 1993, 1995, 1998 and 2000).

1. Under presettlement fire regimes, fire played a role in structuring all natural vegetation of the coastal plain, piedmont and mountains, except those vegetation types that are restricted to natural fire refugia like steep fire-sheltered slopes, islands and peninsulas.
2. Elimination of fire from a pyrophytic landscape initiates succession and replacement of pyrophytic species by non-pyrophytic species and communities.
3. Elimination of fire from a pyrophytic landscape initiates transformation of vegetation structure from one or two layers to multi-storied woody vegetation.
4. Lightning associated with growing-season convection storms drove the fire regime for the Coastal Plain. Native American influence predominated in areas where lightning ignitions were low (Pyne 1982); in portions of the landscape such as floodplain islands that are naturally isolated from fires on uplands (Harper 1911), or in more dissected topographic regions where lightning ignitions were high but fire compartments were small.
5. Landscape factors, such as fire compartment size, control fire frequency.
6. Landscape factors, such as landscape position, slope, aspect and soils, control fire intensity through effects on both vegetation and fire behavior.
7. Frequent fire vegetation and nonpyrophytic vegetation do not abut each other without some interaction. In the natural landscape there are fire-tension zones ranging in width from a few meters to several miles. Many rare species and important vegetation types, such as mixed pine savanna or pyrophytic woodland, were found only in such zones.

TABLE 21. Physical and Biological Components of Landscape Fire Ecology. Characteristics that affect fire frequency, fire intensity and fire effects on vegetation.

PHYSICAL

___Fire compartment size.
___Corridors and windows for fire flow between fire compartments.
___Orientation of fire compartments and corridors to the prevailing winds during fire season.
___Fire shadows.
___Distance from nearest firebreaks.
___Fire filters—landscape and vegetation features that temporarily reduce fire intensity or rate of spread.
___Soil texture. In flat landscapes, soil texture can control fire frequency and fire effects through its influence on vegetation. There can be found 'islands' of mesophytic communities on moist clay soils in a sea of pyrophytic vegetation.
___Depth to water table (especially outer Coastal Plain and upland flats of the middle and inner Coastal Plain and Piedmont).
___Slope & aspect.
___The soil series. While delimited by humans, and subject to frequent errors in mapping, soil series represent real noda of complex environmental variables in the multidimensional soilscape. The soil series, being much more enduring than vegetation, is the most useful mapping unit for putting boundaries on presettlement vegetation.
___Ignition source, lightning versus Indians.
___Land surface form (Hammond 1964).

BIOTIC (Vegetation)

___Pyrogenicity, the physical and chemical influence of vegetation on fire behavior, mediated by ignitability and fire-carrying capacity of living and dead vegetation, and also by litter decomposition rates.
___Fuel structure of live fuels, standing dead fuels, and litter.

Landscape-scale fire frequency gradients. In general, flat landscapes can be expected to have large fire compartments and a correspondingly high fire frequency. On the Coastal Plain, however, I have seen several situations where, within a single fire compartment, vegetation changed along a fire frequency gradient. In some cases this gradient was long attenuated, extending from a frequent-fire area, to an area with lower frequency, to an area with 100 year fire-return interval or no fire at all. These occur primarily in peatlands or areas in Florida where fire flow is obstructed by numerous small lime sinks deep enough to hold water during fire season.

Evaluating Firebreaks

Factors listed below are considered when evaluating streams, swamps and steep slopes as potential firebreaks or as fire filters (factors that slow down the rate of spread, increasing the probability for fire to go out with rain events or night time humidity).

Firebreak factors are evaluated under the assumption of conditions of an average uncontrolled wildfire in presettlement vegetation—warm, dry, conditions with light to medium winds such as occur frequently

during spring fire season. Severe burning conditions are not considered since effects of all but the largest firebreaks as well as of fire filters and fire compartment size become irrelevant.

Quality of channel:
Width of standing water in channel (ft).
Topographic factors:
Depth to which channel incised below floodplain or slope toes.
Channelized or ditched?
Incised more deeply as the result of anthropogenic erosion?
Quality of floodplain:
Continuity:
___Channels, ponds & oxbows increase fire filter effect? (1-5)
___Wet microtopography create a fire filter effect?
___Present or past impoundment effects?
Quality of floodplain litter fuels:
___Continuity of fuel (1 continuous-4 almost too patchy to carry, 5 absent or won't carry)
___Fuel types
___Depth of litter fuels (cm)
___Structure of litter fuels
___Longevity of litter fuels (1-5) before flood removal or decomposition to non-fuel
Quality of shrub layer fuels:
___Fuel species
___Fuel species dense enough to carry fire? (1-3)(1 unlikely, 2 likely under moderate burning conditions, 3 would carry fires under typical wildfire conditions).
___Likely fire intensity based on fuel density under presettlement fire regimes (1-5)(1 barely competent to carry fire, 3 moderate intensity fires such as those in bottomland canebrakes hot enough to carry cleanly but without enough intensity to kill canopy trees, 5 high intensity canebrake or pocosin fires with potential to produce 40 ft flame lengths).
Quality of side slopes:
___Elevation from floodplain to top of slopes (feet)
___Slope percent.
___Potential transport of firebrands/glowing leaf parts across firebreak? (1-5 wi 1 lowest)

Continuity of firebreak (are there fire channels or places where fire could cross an otherwise good firebreak?

TABLE 22. KINDS OF EVIDENCE FOR PRESETTLEMENT FIRE FREQUENCY AND PRESETTLEMENT VEGETATION
Asterisks indicate degree of usefulness, with four being most valuable.

LANDSCAPE AND ENVIRONMENTAL FACTORS:

****	Original fire compartment size.
***	Presence of fire barriers and fire filters: landscape factors, which resist flow of fire between compartments (steep slopes, water bodies, and certain vegetation and soil types).
***	Soil maps and observations of fire behavior on different soil types.
**	Lightning ignition records.
*	Records of size of area burned by wildfires.

HISTORICAL EVIDENCE: **** Early survey plats with witness trees, verbal descriptions of vegetation, and vegetation sometimes sketched on survey plats. **** Historical records mentioning fire frequency indicator species and indicator vegetation types. ** Historical references to fire or fire frequency. ** Historical references to use of fire by Indians. ** Vegetation on old photos and aerial photos. * Palynology and varved lake sediments. EVIDENCE FROM REMNANT NATURAL VEGETATION **** Observations of vegetation structure, by layer, under known fire regimes. **** Fire scar dating. *** Studies of vegetation response to fire exclusion (on each soil series). *** Vegetation response to reintroduction of fire (on each soil series). **** Presence of remnant fire frequency indicator species. *** Presence of remnant fire frequency indicator communities. **** Presence of fire-refugial species with individuals old enough to predate fire suppression.

TABLE 23. FIELD METHODS (for each soil series)

1.	Verify soil taxonomy in the field and correlate soil with vegetation types.
2.	Assemble complete species list by vegetation layer (canopy, subcanopy, shrub layer, herb layer). Make cover estimates by layer to gauge degree of woody succession. Record existing community type and make preliminary estimate of presettlement community type.
3.	Examine vegetation change along local soil, moisture and fire frequency gradients.
4.	Determine recent fire history from fire char, fire scar cores, shrub stem age classes.
5.	Determine extent of human disturbance history, including any evidence of turpentining, logging, grazing and fire suppression.
6.	Determine fire compartment size.
7.	Assign first estimate of presettlement fire return interval.
8.	Determine number and effectiveness of natural firebreaks.
9.	Collect any local and regional records of original vegetation.
10.	Assemble any historic and recent vegetation records and studies from other parts of the southeastern landscape that may apply.
11.	Record any fire-frequency indicator species, either extant or in the historical record and map them onto the specific soil series on which they are or were found.
12.	Assign tentative estimates of recent fire frequency and revise original fire frequency estimate.
13.	Assign tentative estimates of presettlement vegetation type and species dominants.
14.	Determine variation, if any, by slope and aspect.
15.	Determine range of variation in vegetation between pedons of the same soil series within the study area.

A complete list of all species present on each soil pedon examined was compiled; unknown specimens were pressed for herbarium identification. Cover values were obtained for each stratum. The following ten cover classes, defined by the North Carolina Vegetation Survey (Peet et al. 1998), were used for plots on Fort Stewart:

COVER SCALE			
10	95-100 %	5	5-10
9	75-95	4	2-5
8	50-75	3	1-2
7	25-50	2	0-1
6	10-25	1	Trace (as with one seedling, no appreciable cover)

Cover area for each species, by layer, was estimated for an area of about 100 meters square and then adjusted while wandering through the plot. The species lists and cover values are roughly equivalent to those that would be obtained from 1/10 hectare plots.

Synthesis and Mapping

After obtaining soil photomaps and assembling the historical data, the method consists of the following major steps. Plant taxonomy generally follows Kartesz (1994). Following are some guidelines for this stage of mapping.

1. Approximating presettlement community types.
a). Sample remnant natural vegetation on each soil series in the area under study, according to the scheme in Table 23 above. This should include burned examples if fire is believed to have played a role in presettlement vegetation. If some series have no natural remnants, then sample remnants on the same soils in any nearby counties for which they are available.
b). Watch for fire frequency indicator species (such as pitcher plants, wiregrass (*Aristida beyrichiana*), wet savanna species, and fire-frequency indicator communities (like canebrake, *Pinus glabra* or magnolia forest), both in the field, in herbarium records, and in the historical record. Each site for these indicators can be assigned a fire frequency, based on the known range of fire frequency tolerance or intolerance for each species. Adjust these figures slightly upward or downward depending upon soil type and topographic situation and degree of fire shelter or fire exposure for each specific occurrence.
c). Build species lists and make cover estimates by layer (canopy, subcanopy, shrubs, herbs, vines) for all communities on each soil series, under natural fire regimes, and under fire suppression. Learn to recognize the degree of fire suppression for each.
d). Record evidence of successional changes resulting from fire exclusion, reduction in fire frequency or change in season of burn.

2. First approximation vegetation map. Decide upon appropriate mapping units like hardwood hammock, pine savanna, or canebrake, and assign vegetation types to each slope class of each soil series. Group related soils with similar vegetation and assign a color to each group on GIS.

3. First approximation presettlement fire frequency map. Using a copy of the soil series base map, plot all known existing or historical fire indicator species and communities. This should begin to yield a picture of the regional pattern of fire regimes. Where data are scarce, it is useful to reconstruct fire frequency over the larger region that includes the study area. Since there will then be many more examples found, the information can be extrapolated to portions of the study area where information is lacking. Threading contours along lines of equal fire frequency will produce something like a topographic map, only the isopleths will represent different fire-return intervals, or different levels of fire effects, rather than elevation. Alternatively, fire frequency can be mapped by fire compartment (as at Grand Bay).

4. Second approximation vegetation map. Compare the first map of vegetation with the first fire frequency map. At this point some adjustments can be made and areas needing more field work will become obvious. Return to the field to resolve any apparent discrepancies, such as frequent-fire vegetation types and non-pyrophytic vegetation that occur in immediate proximity (this may not be an error—there may just be a locally steep fire-frequency gradient). Pyrophytic wetlands usually require further work because they may have more than one vegetation type on the same soil series. The effects of local natural firebreaks may need to be investigated.

5. Readjust the vegetation map, using the new field data.

6. Refine the fire frequency map, using any new fire frequency data and the adjusted vegetation map.

7. Return to the historical record for discussions or information that may be better interpreted now, after the questions are better known.

8. Refine both the presettlement vegetation and fire frequency maps, using any new insights from the historical record. At this point there will probably be more field questions to answer. There may be more iterations of steps 5, 6, 7 and 8 before a final map is arrived at.

ORIGINAL FIRE REGIMES OF GRAND BAY/BANKS LAKE

Geomorphic setting and fire. The landscape occupied by the Grand Bay wetlands is composed of three broad, flat surfaces stepped one above the other, with the lowest surface represented by the Alapaha River floodplain of Quaternary age. The Alapaha bottomland is bounded on its western margin by a low fluvial scarp about 35 feet high with a toe running around 150-160 feet and top around 190 feet. Above this scarp is the flat plain on which the city of Lakeland is located, with elevations running mostly around 200-210 feet. This surface (Coharrie Terrace?) may be Pliocene or Pleistocene in age. The Grand Bay/Old Field Bay, Banks lake wetlands occupy a series of depressions in this plain which is bounded on the west by an old marine or fluvial scarp about 40 feet high with toe around 191 feet in Old Field Bay and upper edge around 230 feet at Moody AFB where it is most conspicuous. This upland ridge, which forms the divide between Grand Bay and Cat Creek, is dominated by the well-drained Tifton series, a classic longleaf pine soil type.

Topography and elevation. The highest point in the natural area seems to be 247 feet at the USGS benchmark on SR 125 on the northwest side of Grand Bay. Elevations of around 240 feet appear with relative consistency along the top of the southwest-northeast trending scarp bounding the west side of the preserve and capped by the settlements of Bemis, Moody AFB and Barretts. Northeast of Barretts the scarp drops off to a flat only 4-9 feet above the Banks Lake water level and this flat extends all the way east through Lakeland to the fluvial scarp above the Alapaha River. With exception of the Alapaha River bottom, the lowest point in the original landscape was the former Mill Creek channel, now in the bottom of Banks Lake. Milltown Bay, Banks Lake, Peters Bay, Copeland Branch, Alligator Run and the eastern portion of Old Field Bay formerly drained through this low point.

Control of Regional Fire Frequency by Landscape Factors

The flat to gently rolling ridge of former longleaf pine land along SR 125 runs slightly southwest-northeast, aligned with the prevailing winds, all the way south to Valdosta and beyond. This provides one of two major corridors for fire flow in the region. Several factors make for this surface being the most fire

frequent portion of the natural area, including: 1) fire compartment size, 2) alignment with the prevailing winds during fire season, and 3) continuity of presettlement fuels.

Fire compartment size. Given a region with a source of ignitions, whether from lightning or Native Americans, fire frequency is driven by fire compartment size (see Methods section above). The larger the fire compartment the higher the fire frequency (Frost 1998, 2000). The upland Tifton soils form a continuous fire compartment running many miles north/south. This alone should indicate this as the most fire frequent surface in the region.

Alignment with winds prevailing during fire season. The body of Tifton soils from near Ray City to Valdosta and south, are aligned with the winds from the south and southwest that prevail during the spring fire season. This would have provided a high rate of fire spread in the original winter-cured fuels of longleaf pine needles and wiregrass. Rapid downwind fire spread would serve a source ignition for slower moving flanking fires moving into the natural area and even slower backing fires to add coverage of less accessible areas. Wildfires would have peaked during fire season, a time that we avoid for prescribed burns because of the hazard of uncontrolled fire spread, and the average wildfire would have occurred under conditions of lower fuel moisture and higher winds than we would now risk with prescribed fire. Consequently, vegetation of the original landscape was very much more influenced by fire.

Fuel continuity. Before fragmentation of the fire landscape by roads, ditches, cleared fields and towns, fire compartments would have been large and their fuels of longleaf pine needles, wiregrass and other graminoids would have been nearly continuous, so that an ignition one part of a compartment would likely burn the whole unless extinguished prematurely by rain or high night time fuel moisture, uncommon during spring fire season. Small drains, up to and including those such as Cherry Creek and Grand Bay Creek, represented much less of a factor as firebreaks under the original fire regimes as they would have then had more fire-maintained wetland grasses and sedges, flammable cane, and patches of bay-gall with low stature maintained by fire. All of these provided fine textured wetland fuels, serving to increase the facility of fire passing through such wetlands. Fire exclusion from wetland drains results in development of a tall canopy with multistoried woody vegetation, resulting in increased shade and elimination of flammable cane and other graminoids. As a result, fire suppressed small wetlands become better firebreaks or fire filters, while in the original landscape most fires would have passed through them easily even without resort to spotting or other effects accompanying severe burning conditions.

Firebreaks and Fire Filters. Small wetlands, such as beaver ponds and Carolina bays, at the density at which they occur in the Grand Bay region, would have had little effect on the regional fire frequency. In the lime sink pond regions of Florida, where their numbers are dense upon the landscape, they significantly reduce fire flow. When they are numerous and deep enough to pond water during fire season these pond-dappled landscapes act as regional fire filters, decreasing rate of spread, providing numerous downwind fire shadows and decreasing the overall regional fire frequency. With exception of Banks Lake and parts of Old Field Bay and Moody Bay, most of the Carolina bays and lime sink depressions in the Grand Bay region were only seasonally ponded and most would have carried fire under the original fire regimes. With long fire suppression most have lost their grass-sedge, cane and low shrub components making them less flammable. When fire is reintroduced to such systems the most conspicuous immediate effects are enhancement of any remnant wetland graminoids, and stem kill of tall shrubs and saplings especially in the small diameter classes up to 1 and 2 inches. Repeated fire result in more continuous, graminoid cover on wet mineral soils, dense fire-resprouting low shrub cover or cane in mucky areas, hotter fires with stem kill of larger understory saplings and fires moving deeper into wetlands. After several burns, which build fuel continuity, fires may pass all the way through small wetlands as they did under natural fire regimes.

Similarly, on the east side of the natural area, in the vicinity of US 221 and US 84, while not as dry as the Tifton uplands, southwest-northeast trending uplands form a major route for fire flow along US 221 and the

railroad and also, to the east, along the well-drained upper shoulder of the Alapaha River Scarp which represents the eastern margin of the Lakeland plain.

Elevation of the agricultural portions of this plain run 200-210 feet, only 10-20 feet above Banks lake water level (but 20-30 feet above the original bottomland, a considerable difference in a landscape where microtopographic changes result in significant vegetation differences. This flat, moderately well-drained to poorly-drained plain is mantled with moist longleaf pine savanna soils. The dominant series, from driest to wettest, are the Stilson, Leefield, Albany, Olustee, Alapaha, Mascotte and Pelham—the wettest soil to regularly support longleaf pine savanna (and then only in its drier phase). All of these moist longleaf pine soils are subject to invasion by slash pine, loblolly and hardwoods with reduction in fire but in the original landscape the moist savannas would have supported a rich ground cover forming a continuous fuel layer and would have experienced nearly the as high a fire frequency as on the dry Tifton soil uplands to the west (see accompanying GIS fire frequency map).

Relative Fire Exposure of the bays. At the southern end of the wetland complex, Grand Bay is the most fire-exposed of the wetlands and, being shallow, would have experienced the highest fire frequency (see fire frequency map). Grand Bay itself represents the terminus of several fire paths originating many miles to the south. Fires could spread into the bay from the longleaf pine uplands to the southwest, the major fire highway in the region, from the gently rolling flats to the south of Knight's Academy road and from the moist longleaf pine savannas on the flats extending from Becky Bay all the way south to the Mud Creek vicinity. Considering that a few fires, such as those moving into the area at night under conditions of little or no wind, would not have carried through the marshy vegetation of Grand Bay, its fire frequency would have been a little less than the 1-3 regional fire frequency, but still high with a mean fire interval of around 4 years and an estimated historic range of variation (HRV) of 1-9 years. Ninety percent of fires would be expected to fall within this range. An HRV of 1-9 means that fires could occasionally occur back to back while a fire-free interval of as long as 9 years would occur occasionally . Rarely there would be a longer interval without fire.

Dudley's Hammock, the most fire-sheltered feature in the wetland complex, occurs at the other extreme of the fire frequency gradient. It is sheltered by multiple features that would progressively subtract many of the fires passing through the region and the surrounding black gum swamp would provide the final firebreak. It is sheltered first by Becky Bay to the south and then by the small north/south drain that originates near Becky Bay and drains west across US 221 and then north into Grand Bay Creek. Since flanking fires have less force than head fires, north-south drains are more effective firebreaks because they are aligned with the prevailing winds, while east-west drains are more likely to be jumped by wind-driven fire. Another drain, the major one from Becky Bay, drains northeast from Becky Bay, paralleling US 221 on its east side and emptying into Grand Bay Creek providing a hurdle for fires moving up from the south and southeast. Fires from the west or from the south near the education center would have to jump the significant firebreak created by the southern arm of Grand Bay Creek itself. Finally, any fire that made it this far would find itself having to be able to spot over the swamp surrounding Dudley's Hammock. While occasional fires would spot in, they would have had little effect other than removing litter and the smaller diameter classes of shrubs and saplings, mostly in the 1-2 inch range. An occasional fire would support the maintenance of oaks and prevent ultimate dominance of magnolia.

Principal season of burn in the original landscape would have been the March-April fire season with some secondary fall burning by Native Americans.

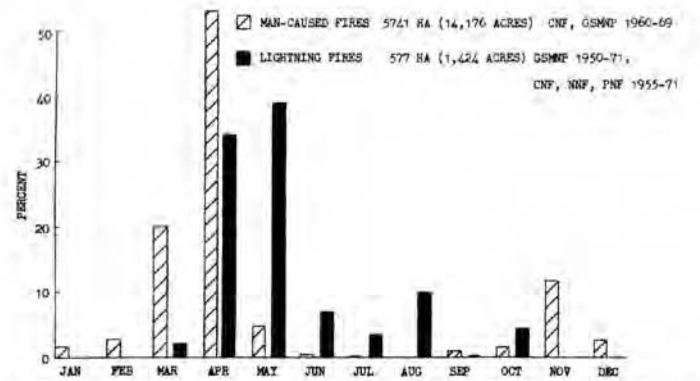

FIG. 2. Incidence of wildfires in the Appalachians of Tennessee and North Carolina

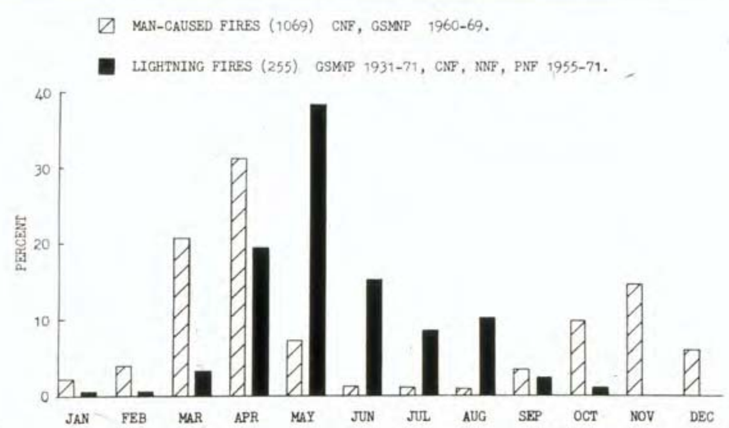

FIG. 3. Area burned by wildfires in the Appalachians of Tennessee and North Carolina.

Figures from Barden and Woods 1973, show the history of wildfires in the Southern Appalachians compiled from USFS records. Peak fire season, the time when lightning ignitions are most frequent and also the time when fires travel farthest, is around May in the mountains. In south Florida the peak occurs around February-March, and on the mid-Atlantic coastal plain it occurs in March and early April. This corresponds not to peak lightning strike density but to the time when there is the largest amount of dry, winter-dead fine fuel available to carry fire. In presettlement times a second fire season was related to annual fall burning carried out by Native Americans.

The Grand Bay/Banks Lake region is in the highest fire frequency band of the southern U.S. where the original fire frequency, primarily based on lightning on the coastal plain, with some supplemental effect by Native American burning, averaged as high as 1-3 years (Figure 16 below).

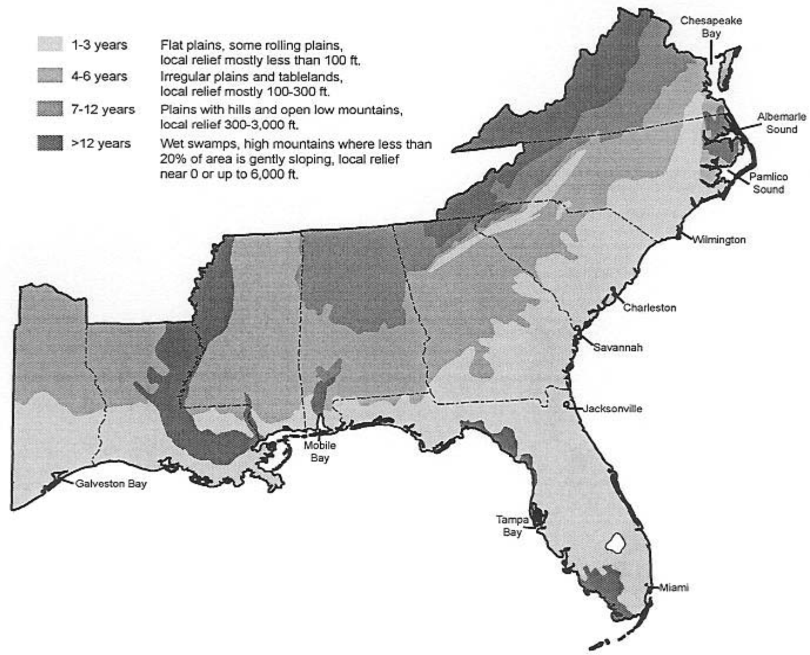

Figure 16. Presettlement fire regimes of the southeastern United States. Derived from regional fire compartment size, topography, historical records, climate, vegetation remnants and soils. Frequencies are only for the most fire-exposed parts of the landscape. Each region also contains variously fire-protected areas with lower incidences of fire (Frost 1995).

The map represents only the highest fire frequencies in each region, however, the most fire exposed sites on broad uplands (representing large fire compartments), ridges and dry south slopes. Within each region there were variously fire sheltered areas depending upon local landscape factors. To get at these a detailed local fire frequency map was produced using the methods discussed above. Table 21 below illustrates the 8 fire frequency classes used for the historical fire regimes map (GIS map copies and electronic versions submitted separately).

Fire Frequency Class	Mean Fire Interval (years)	Estimated Historic Range of Variation (90% of Fires) (years)	ACRES	PERCENT
A	1.5	1-3	7,246	23.4
B	2	1-4	5,300	17.2
C	3	1-6	4,465	14.5
D	4	1-9	2,580	8.4
E	5	2-20	480	1.6
F	7	4-100 depending upon location in the landscape	202	0.7
G	Variable	complex fire patterns in small, fire-exposed drains	2,164	7.0
H	Variable	bottomland forests, small savannas and bays with variable fire influence	8,436	27.2
		TOTAL	30,873	100

Table 24. Original fire regimes at Grand Bay/Banks Lake

Management implications of the historic range of variation in fire frequency. For each fire frequency class the estimated mean fire interval (MFI) is given. The third column represents the estimated historic range of variation (HRV) in fire intervals Note that both the MFI and HRV ranges are skewed to the left. This is because, in a frequent fire region nearly saturated with ignitions, it is possible to have fires back to back on the left side, but that is the highest frequency you can have (discounting rare and ecologically insignificant instances of two fires in spring and fall of the same year). On the right side, however, even though the mean fire interval might be four years, there can be rare intervals with longer times between fires. This make sense since with the El Nino/La Niña southern oscillation (ENSO), there may be natural sequences of several wet and several dry years. This allows for considerable freedom in management with fire. For best approximation of a MFI of three, for example, it is not necessary to rigorously burn every three years (although that may not have any negative effects). It might be desirable to occasionally have two fires in a row and to have occasional fires at longer intervals. As long as the MFI of three were maintained this should approximate the natural fire interval.

Fire frequency indicator species. A relatively small percent of the site needs a frequent (1-3 year) fire regime (see fire frequency class A on the GIS map of original fire frequency). Of particular importance are those sites with rare fire dependent species. Some plant species that appear to be fire frequency indicator species for the 1-3 year fire interval that occur in the Grand Bay region are *Sarracenia minor* and *Sarracenia flava*. The yellow trumpets, in particular, are dependent upon full sun provided by fire that keeps its habitat open and would probably not be persisting at the preserve except for the unusual habitat provide by the floating vegetation mats resulting from anthropogenic flooding. Wiregrass is a fire frequency indicator species but with a wider range, 1-7 years. Fire-dependent rare animals species once present would have included the red-cockaded woodpecker. Throughout the South there are several hundred rare plants, birds and animals that are rare simply because of the disappearance of natural fire regimes, beginning with the widespread success of effective fire suppression after World War II.

PRESETTLEMENT VEGETATION OF GRAND BAY/BANKS LAKE

Presettlement Vegetation and Soils

Table 25 below, shows original vegetation types with their primary soils arranged approximately from driest to wettest. Terms used are soil series name and soil texture, soil series codes (codes are sometimes different in Lowndes and Lanier counties), counties of occurrence in parentheses (LA = Lanier, LO = Lowndes), soil taxonomy, NRCS drainage classes (ED = excessively drained, etc), and depth to seasonal high water table in feet. A plus sign, e.g. +1, means that there is a foot of water standing on the surface at time of seasonal high water table. Each soil series is followed by one or more symbols for vegetation types occurring on that series, with the symbol for the most abundant type shown first.

Symbols for original vegetation types in Table 26 below.

☐ Longleaf pine, xeric to mesic longleaf pine/wiregrass savanna & longleaf pine/turkey oak
☼ Wet-mesic Longleaf Pine Savanna
⌂ Wet Mixed Pine Savanna (various combinations of longleaf, slash and pond pine & sometimes loblolly & cane)
★ Pyrophytic Hardwood Woodland (live oak, post oak, white oak, southern red oak, scrub oaks)
● Mixed Mesic Hardwood Slopes (pignut hickory, live oak, *Magnolia grandiflora*), laurel oak, water oak, sweetgum.

♠ Hardwood Hammock
▼ Bottomland Hardwoods
▲ Pine Flats (loblolly and slash pine with bottomland hardwoods such as swamp black gum)
◊ Pond Pine Savanna & Forest (with a fire maintained grassy understory)
○ Canebrakes: pond pine canebrake, mixed longleaf pine-pond pine canebrake, and hardwood canebrake
◘ Bay-Gall and Pond Pine Pocosin
¶ Small Depression Ponds and Sloughs, intermittently flooded
♦ Small Stream Swamp and Pyrophytic Wetland Mosaic
■ Bottomland hardwood and swamp forest (now flooded) complex
Ω Fresh Marsh, Pools and Bogs (Andropogon, Eleocharis, Scirpus, Dulichium, Rhynchospora, Xyris, Nymphaea, Brasenia, Sagittaria, diverse marsh graminoids & forbs, with scattered slash pine)

Table 25. Presettlement Vegetation and Soils:

1. Dry-Mesic Longleaf Pine/Wiregrass Savanna □
Lakeland sand, LaC (LO), LwC (LA) – coated Typic Quartzipsamments, ED, >6 □

2. Mesic Longleaf Pine/Wiregrass Savanna □
Tifton loamy sand TfA, TfB, TuB (LO), TqA, TqB (LA) – fine-loamy, siliceous, Plinthic Paleudults, WD, >6 (TuB = disturbed soils at Moody AFB) □
Fuquay loamy sand, FsB (LA & LO) – loamy, siliceous, Arenic Plinthic Paleudults, WD, 4-6 □
Dothan loamy sand, DoB (LO), DaB (LA)– fine-loamy, siliceous Plinthic Paleudults, WD, 3-5 □
Carnegie sandy loam CoB (LA) – fine-loamy, siliceous, Fragic Paleudults, WD, >5 □
Stilson loamy sand Se (LO), SeB (LA) – loamy, siliceous, Arenic Plinthic Paleudults, MWD, 2.5-3 □
Irvington loam sand IjA (LA) – fine-loamy, siliceous, Plinthic Fragiudults, MWD, 1.5-3 □ ♠
Chipley fine sand ChA (LO) – coated, Aquic Quartzipsamments, MWD, 2-3 □
Clarendon loamy sand Cn (LO) – fine-loamy, siliceous Plinthaquic Paleudults, MWD, 1.5-2.5 □

3. Pyrophytic Longleaf Pine-Hardwood Woodland and Mesic Hardwood Forest on Side Slopes ★
Carnegie sandy loam CoC2 (LA) – fine-loamy, siliceous, Fragic Paleudults, WD, >6 ★ ●
Cowarts loamy sand CqB (LA) – fine-loamy, siliceous, Fragic Paleudults, WD, 2-3 ★ ●

4. Mesic Hardwood Hammock ♠
Hammocks occur on no unique soil type: occurs on At, Mn, Pe, LsA, IjA at Dudley's Hammock, Hickory Hammock and Lightsey Hammock..

5. Wet-Mesic Longleaf Pine Savanna ☼ (red indicates that these are savanna soils with the highest species diversity and with the most dependence upon frequent fire, needing fire at least every three years to maintain diversity)
Leefield loamy sand Le (LO), LsA (LA) – loamy, siliceous, Arenic Plinthaquic Paleudults, SPD, 1.5-2.5 ☼ ♠
Barth Ba, (LA) sand – sandy, siliceous Plinthaquic Paleudults, SPD, 1.5-2.5 (name no longer used, maybe lumped with Leefield) ☼
Albany sand AdA (LO) – loamy, siliceous, Grossarenic Paleudults, SPD, 1-2.5 ☼
Olustee sand Oa (LA & LO) – sandy, siliceous, Ultic Albaquods PD, 1.5-2.5 ☼ ⌂
Alapaha loamy sand At (LA) – loamy, siliceous Arenic Plinthic Paleudults, PD, 0-1 ☼ ⌂ ♠
Mascotte sand Mn (LA & LO) – sandy, siliceous Ultic Haplaquods, PD, 0-1 ☼ ⌂ ♠
Pelham loamy sand Pe (LO), Pl (LA) – loamy, siliceous, Arenic Paleaquults, PD, 0.5-1.5 ¶ ☼ ⌂ ♠

6. Wet Mixed Pine Savanna ⌂
Not limited to one particular series (see mapped units)

7. Pine Flats (loblolly and slash pine with bottomland hardwoods) ▲ ■
Not limited to one particular series (see mapped units)

8. Lime Sink Depressions ¶
(with pond cypress, pond pine, swamp black gum, wetland graminoids)
Pelham loamy sand Pe (LO), Pl (LA) – loamy, siliceous, Arenic Paleaquults, PD, 0.5-1.5 ¶
Grady sandy loam, Gr (LO), Grd (LA) – clayey, kaolinitic Typic Paleaquults, PD, +2-1 ¶

9. Clay-based Bays Ω
Dominated by graminoids with scattered slash pine, scattered peripheral swamp black gum and pond cypress.
Portsmouth loam Por (LA)– fine-loamy over sandy or sandy-skeletal Typic Umbraquults, VPD, +1-1 Ω
Natural examples of Portsmouth soils can be seen in Monk Pond and the wetland just to its northwest. All other units mapped as Portsmouth in the natural area are artifacts of flooding and have been assigned to several original vegetation types.
Bayboro loam Bm (LO) – clayey, mixed, Umbric Paleaquults, VPD, 0-1 Ω
(In the natural area, soils classified as Bayboro would not have occurred as Bayboro loam in the presettlement soilscape. Bayboro classification now is based on substrates that have been impounded and long fire suppressed, leading to accumulation of more organic thickness than could have been found in nature.)

10. Small Stream Swamp and Pyrophytic Wetland Mosaic Structured by Fire and Beaver ♦ (mosaic elements include swamp black gum, pond cypress, bottomland hardwood forest, hardwood/canebrake, pond pine/canebrake, bay-galls, beaver ponds and freshwater marsh created by beaver).
Johnston loam Jo (LO) – coarse-loamy, siliceous, acid, Cumulic Humaquepts, VPD, +1, 1.5 ♦
Johnston-Osier-Bibb mosaic Job (LA) ♦:
Johnston loam, coarse-loamy, siliceous, acid, Cumulic Humaquepts, VPD, +1, 1.5
Osier loamy fine sand, siliceous, Typic Psammaquents, PD, 0-1
Bibb fine sandy loam, coarse-loamy, siliceous, acid, Typic Fluvaquents, PD, 0.5-1.5
Pelham "low terrace" Pls (not the true Pelham series which is drier). Pls is mapped in drains that modern taxonomy would likely classify this as Ellabelle or a similar basement series wetter than Pelham, VPD, +1, 0.5 ♦ ⌂ ☼

11. Slash Pine, Swamp Black Gum, Pond Cypress, Sweet Bay Flats and Wetland Complex ■
Swamp Swa (LA) – no taxonomy given: artificially flooded soils, VPD.
Istokpoga complex, Ist (LA) – dysic, hyperthermic Typic Medihemists, VPD, 0-1 (series name is no longer used: see the similar Dasher in Lowndes County). Istokpoga likely to have been something else in original, unimpounded landscape (named for a soil series in Florida).
Dasher muck Da (LO) – dysic Typic Medihemists (Haplohemists), VPD, +3-0.5 (an artificial soil type created by intentional flooding). "Dasher" likely to have been a complex of bottomland mineral soils in original, unimpounded landscape.
Banks Lake – originally a bottomland before damming up for a mill pond.

12. Udorthents and other disturbed soils (gray color for disturbed soils)
B.P. – Borrow pits

13. Water: Aquatic communities of lakes, streams and semipermanently flooded lime sinks, beaver ponds and Carolina Bays**.**

	SOIL MOISTURE					
SOIL TEXTURE	ED	WD	MWD	SPD	PD	VPD
Sand	Lakeland			Albany, Barth	Olustee, Mascotte	
Loamy Sand		Tifton, Fuquay, Dothan, Cowarts	Stilson, Irvington Chipley, Clarendon	Leefield	Alapaha, Pelham, Osier	(Rutlege) [Ellabelle or similar]
Sandy Loam		Carnegie			Grady Bibb [Rembert] [Ogeechee]	[Cape Fear or similar]
Loam					[Meggett]	(Bayboro) Johnston (Portsmouth)
Histosols (organic)						(Istokpoga) (Dasher)

Table 26. Grand Bay/Banks Lake Soils ranked according to gradients of soil texture and moisture. Within cells the driest soil is listed first. Soils in parentheses are mostly the artificial result of impounding and would have been moist mineral soils in the original situation. These submerged former soils consist of a mosaic of some of those listed in the PD (Poorly Drained) column above as well as some VPD mineral soils such as Cape Fear and Ellabelle series that have no unimpounded examples to appear on the soil map. Similarly, since the lowest soils were closest to the marl layer underlying the natural area, there may have been some patches of circumneutral Alfisols. Canebrake is likely on such wet soils where accessible to frequent fires. Soils in brackets are not mapped in either county but occur elsewhere as wet basement soils or wet mineral soil substrates in shallow Carolina bays.

There are some unimpounded Bayboro soils in Lowndes and Lanier but those mapped in Grand Bay, Moody Bay and Old Field Bay are clearly artifacts of flooding and fire exclusion. While there may have been small pockets of Rutlege and Portsmouth soils, those appearing now on the soil maps are flooding artifacts. There was likely nothing that could be mapped as Istokpoga or Dasher in the original landscape.

Figure 17. Old pine heartwood trunk on left was once part of a forest in a bottomland flat and is a remnant of virgin forest that predates impounding of Banks Lake. Ages ranged from 50 to 200 years when killed by flooding after construction of Banks Lake mill dam around 1827-1835. Deepwater pond cypress such as the one on right may also predate the 1830 dam while much of the younger stands around shorelines likely developed in shallow water and were supplemented by stems originating during droughts and periods when the dam washed out.

Heartwood remnants of trunks of virgin pine established before 1830				
Diameter of remains at 24 inches above full pool water level (cm)	Full pool water depth (after subtracting 10 cm for water flowing over top of weir on day of measurement (meters)	Fire char present on trunk above water level? (yes/no)	Approximate Date of Establishment (before killed by flooding ~1830)	Notes
36	1.6	Y		
36	1.8	N		
18	1.8	N		
22	1.6	Y		
24	2.0	N		
19	2.1	N		
34	2.1	N		spiral grain like pond pine
35	2.2	N	~1783	~42 years + 5 yrs to reach 2 meters = 47
34	2.2	Y		
45	2.2	N		
33	2.2	N	~1625	~200 yrs (94 rings in outer 11 cm)
32	2.2	N		

Table 27 shows water depths and diameters of old pine heartwood stumps in Banks Lake. Ages range from around 50 to 200 years when killed by flooding after construction of Banks Lake mill dam around 1830. 200 years before present would be 1806, before settlement. The implication is that trees 50 years old, killed within a few years of flooding, say 1835, would have germinated in 1785 and a 200 year old tree would have germinated in 1635. They are presumably mostly slash pine but could also be longleaf and pond pine or a mixture of the species since all three produce resinous heartwood and all can be found on moist soils. In contrast, loblolly pine would have rotted away within a few years. Presence of fire char on the dead wood indicates a fire at some time when the lake was drained, perhaps during the period of several years after the 1921 draining. The highly variable relationship between diameter and age (one 35 cm tree was 42 years old while a smaller tree was apparently over 200 years) suggests irregular regeneration in the bottomlands and variation in competition with other species such as swamp black gum and sweet bay.

ACREAGES OF ORIGINAL VEGETATION TYPES OF GRAND BAY/BANKS LAKE

Table 28 below summarizes acreages from the accompanying GIS map of presettlement vegetation.

Vegetation Type	ACRES	%
Dry-Mesic Longleaf Pine/Wiregrass Savanna	25	<0.1
Mesic Longleaf Pine/Wiregrass Savanna	6,805	22.0
Pyrophytic Longleaf Pine-Hardwood Woodland and Mesic Hardwood Forest on Side Slopes	26	<0.1
Mesic Hardwood Hammock	135	0.4
Wet-Mesic Longleaf Pine Savanna	8,065	26.1
Wet Mixed Pine Savanna (longleaf, slash, pond pine)	305	1.0
Pine Flats (loblolly, slash, pond pine, longleaf & swamp hardwoods)	695	2.3
Lime Sink Depressions	2,201	7.1
Clay-based Bays	1,696	5.5
Small Stream Swamp and Pyrophytic Wetland Mosaic Structured by Fire and Beaver	2,039	6.6
Slash Pine, Swamp Black Gum, Pond Cypress, Sweet Bay Complex	8,816	28.6
Udorthents, Borrow Pits and other disturbed soils	4	0.01
Water and Aquatic Communities	61	0.2
Total Wetlands	15,813	51.2
Total Upland acres	15,060	48.8
TOTAL	30,873	100

Table 28. Number of acres in each presettlement vegetation type.

VEGETATION DESCRIPTIONS

Original Natural Habitats for Pines (listed in order of apparent original abundance)

Longleaf pine - overwhelmingly dominant on the drier upland soils and on the low, fire-exposed flats of moist mineral soil. Along with impounding and fire exclusion, elimination of longleaf pine from most of the upland landscape has been the most striking alteration of vegetation in the Grand Bay region.
Slash pine - once common on wet flats and drains (now submerged by impounding of Banks Lake and Old Field Bay). Still common in wet drains such as Grand Bay Creek and all the small sloughs draining into the wetland complex. Slash pine is found occasionally in pure stands on savanna soils just barely too wet for longleaf, but is more typically mixed with other pines and wetland trees such as sweet bay, cypress and swamp black gum. There may have been small patches of slash pine savanna where fire had easy access to moist mineral soils, now submerged.
Pond pine - occurring in two vegetation types: 1) in mixed pine savannas maintained by fire in partly fire sheltered situations on the moist Alapaha, Pelham, Leefield, Olustee and Mascotte soils, and 2) in fire exposed portions of sloughs and creeks having pockets of organic muck accumulation. See the old growth stand in a slough on the north side of the ordnance storage area at Moody AFB.
Loblolly pine – much less abundant in the presettlement landscape but native, with it primary habitat in partly fire-sheltered situations on moist mineral soils. Typical habitat would have been along the toe of the slope forming the western boundary of Old Field Bay (Figure 19) and as a very minor component of hammocks. Now widely escaped onto the uplands after logging in the vicinity of seed trees in these natural refugia and weedy over the rest of the landscape as escapes from loblolly pine plantations.
Spruce pine (Walter's pine, *Pinus glabra*) – a fire refugial species, the least abundant pine in original forests and seen only in the most fire-sheltered situations such as Dudley's Hammock.

Following are descriptions of the vegetation types shown for the presettlement landscape of Grand Bay/Banks Lake on the accompanying GIS map.

Interpretation of soil and vegetation descriptions below: "CT" stands for a typical natural vegetation community type in the original landscape. Vegetation and soils in each group are arranged roughly from driest to wettest. Terms used are soil series name, soil texture and soil series codes (codes for the same soil often differ between Lowndes and Lanier counties), counties of occurrence in parentheses (LA = Lanier, LO = Lowndes), soil taxonomy, NRCS drainage classes (ED = excessively drained, VPD = very poorly drained, etc), and depth to seasonal high water table in feet. A plus sign, e.g. +1, means that there may be a foot of water standing on the surface at time of seasonal high water table. Symbols at the end indicate the most typical vegetation under the original fire regime in fire exposed sites, with the most important shown first. Additional symbols indicate less common vegetation types found on the same soil series, usually in partially fire sheltered situations.

1. Dry-Mesic Longleaf Pine Savanna □

SOIL SERIES: Lakeland sand, LaC (LO), LwC (LA) – coated Typic Quartzipsamments, ED, >6 □

The Lakeland sands vary in depth to water table and so are sometimes dry and sterile, while in other places may be moist enough to provide dense cover of wiregrass and other native grasses. Found in the mapped area only in the town of Lakeland (for which the series is named), all sites have been developed with no natural vegetation examples remaining.

ORIGINAL VEGETATION: Longleaf pine/turkey oak/wiregrass-dry-mesic savanna graminoids and forbs generally with fewer species than in the more fertile types below

CT: *Pinus palustris*/*Quercus laevis*/*Aristida beyrichiana*-dry-mesic savanna graminoids and forbs

2. Mesic Longleaf Pine Savanna □

SOIL SERIES:

Tifton loamy sand TfA, TfB, TuB (LO), TqA, TqB (LA) – fine-loamy, siliceous Plinthic Paleudults, WD, >6 (TuB represents disturbed soils at Moody AFB) □

Fuquay loamy sand, FsB (LA & LO) – loamy, siliceous Arenic Plinthic Paleudults, WD, 4-6 □

Dothan loamy sand, DaB (LA), DoB (LO) – fine-loamy, siliceous Plinthic Paleudults, WD, 3-5 □

Carnegie sandy loam CoB (LA) – fine-loamy, siliceous Fragic Paleudults, WD, >5 □

Stilson loamy sand Se (LO), SeB (LA) – loamy, siliceous Arenic Plinthic Paleudults, MWD, 2.5-3 □

Irvington loam sand IjA (LA) – fine-loamy, siliceous Plinthic Fragiudults, MWD, 1.5-3 □ ♠

Chipley fine sand ChA (LO) – coated Aquic Quartzipsamments, MWD, 2-3 □

Clarendon loamy sand Cn (LO) – fine-loamy, siliceous Plinthaquic Paleudults, MWD, 1.5-2.5 □

ORIGINAL VEGETATION: Longleaf pine/sparse scrub oaks/wiregrass-diverse mesic savanna graminoids and forbs

CT: *Pinus palustris*/mixed scrub oaks/*Aristida beyrichiana*-diverse mesic savanna graminoids and forbs

Soils of this group are less sterile than the Lakeland sand and the cover of wiregrass increases. This group includes the most characteristic soils of the well-drained uplands of the region and is prominent along the old marine shoreline forming the scarp that runs southwest-northeast along the uplands of the western side of the preserve.

Figure 18. Exemplary remnant of natural vegetation on gently rolling Tifton soils. Being among the premier agricultural soils of Georgia, most were cleared for farming by the Civil War. While a major soil type in the area, not a single natural remnant was found in the Grand Bay vicinity. The photo can be considered a snapshot of what the original upland landscape on the west side of the natural area in the vicinity of Bemiss, Moody and Barretts looked like to the first settlers when they arrived to take up their 490 acre lots after the 1820 land lottery. Note the abundant light reaching the ground cover and the distinct two-layered structure typical of longleaf pine communities under a frequent fire regime. Site is in a portion of Fort Stewart that has been burned about every 1-3 years, approximating the original fire frequency.

3. Pyrophytic Longleaf Pine-Hardwood Woodland and Mesic Hardwood Forest on Side Slopes ★
SOIL SERIES

Carnegie sandy loam CoC2 (LA) – fine-loamy, siliceous Fragic Paleudults, WD, >6 ★ ●

Cowarts loamy sand CqB (LA) – fine-loamy, siliceous Fragic Paleudults, WD, 2-3 ★ ●

A few other side slopes with similar vegetation were too narrow to appear as distinct types on the soil and vegetation maps.

ORIGINAL VEGETATION: Longleaf pine on upper slope shoulders, grading into fire resistant oaks such as live oak, post oak and white oak and then into pignut hickory, oaks and *Magnolia grandiflora* on moist, fire-sheltered slope toes and low, moist, fire sheltered flats. Along with hardwood hammocks, these slopes, representing only a tiny percent of the uplands, comprised the only habitats for canopy oaks and hickories in the original landscape.

CT: *Pinus palustris*-mixed oaks (*Quercus virginiana*, *Q. stellata*, *Q. alba*, *Q. falcata*)/diverse mesic slope savanna graminoids and forbs

CT: *Carya glabra*-mixed oaks-*Magnolia grandiflora*/mixed mesophytic shrubs/*Chasmanthium laxum*. The lower slopes constitute partial refugia from fire for thin-barked trees such as magnolia. Unusual species include *Bumelia lanuginosa* (noted by Tip Hon)

Figure 19. Live oak on east-facing slope of Cowarts loamy sand, Ben Strickland farm. The upper slopes also support post oak and other oaks while the lower slope toe in background is dominated by pignut

hickory and *Magnolia grandiflora*. Adjacent wet pine flats have loblolly pine, mixed oaks and tall sweet bay.

4. Mesic Hardwood Hammock ♠
This fire refugial type occurred, as indicated by hammock place names in the area, at Dudley's Hammock, Hickory Hammock and Lightsey Hammock.
SOIL SERIES:
Hardwood Hammock is a feature of position in the fire landscape rather than the soil type on which it occurs. It was found on the Alapaha, Mascotte, Leefield, Pelham and Irvington soils at Dudley's Hammock, Hickory Hammock and Lightsey Hammock
ORIGINAL VEGETATION: almost exactly as found on the south side of the crash trail through the middle of Dudley's Hammock. This is the only example of any vegetation type at the Grand Bay/Banks Lake preserve that can be said to be in almost pristine natural condition.
CT: Diverse mixed mesophytic and fire refugial oaks, magnolias, pignut hickory and spruce pine/*Lyonia ferruginea-Vaccinium* spp.-*Serenoa repens*///mixed arboreal epiphytes..

Dudley's Hammock, on the south side of the gravel road (crash trail), has the best examples of hardwood hammock vegetation on the preserve, with slight variations on the five soil series represented there (Alapaha, Mascotte, Leefield, Pelham and Irvington). This forest type is rare enough in the region to make it desirable to aim for restoration of the disturbed portion of the hammock on the north side of the road if possible. Unusual or rare species include green-fly orchid (*Epidendrum conopseum*) and unusually large specimens of *Lyonia ferruginea* with trunks up to several inches diameter.

Dudley's Hammock is the site on the preserve most isolated from fire. Rare ignitions from long distance spotting would have occurred but would have had no significant effect other than occasional thinning of the understory. It has by far the highest diversity of tree species of any location in the Grand Bay, including such fire-refugial canopy species as spruce pine, magnolia, water oak and swamp chestnut oak. Prinicpal canopy species are *Quercus virginiana, Quercus nigra, Quercus laurifolia, Quercus michauxii, Quercus alba, Quercus phellos, Carya glabra, Magnolia grandiflora, Magnolia virginiana, Liquidambar styraciflua, Pinus glabra, and Pinus taeda.* While loblolly pine is a minor natural component of such hammocks, there is currently an overabundance resulting from succession after past logging. The understory is dominated by *Lyonia ferruginea*, highbush blueberries and *Serenoa repens*. In the absence of fire this is a multistoried woody community with almost no groundcover except for an occasion clump of *Chasmanthium* or *Carex*. Nearly the only other herbaceous species present are the epiphytes *Polypodium polypodioides*, *Tillandsia usneoides* and *Epidendrum conopseum*.

Figure 20. Dudley's Hammock with live oak, laurel oak, white oak, swamp chestnut oak, water oak, willow oak, pignut hickory, magnolia, sweet gum, spruce pine and loblolly pine. This is about how the site would have been expected to look in presettlement forests.

Hickory Hammock (name used by Moody AFB staff) is an island of low mineral soils isolated by Old Field Bay on the north, Grand Bay Creek on the south, a tributary of Grand Bay Creek (Wide Branch or Cooter Creek, as called by Moody AFB staff) on the east and Moody Bay on the west. The southern end of the upland flats is partially sheltered from fire by adjacent swamps and may have been a refugium for pignut hickory, hence the name. The narrow drain on the east side represents only a minor obstruction

from fire and under the original fire regime likely had patches of fire-maintained cane and low, flammable bay-gall vegetation adjacent to longleaf pine uplands to the east side, facilitating fire crossing onto the flats of Hickory Hammock. That this did occur frequently is indicated by the remnants of longleaf pine savanna with relatively diverse understory savanna grasses, forbs and low shrubs toward the northern, downwind end of the island.

Lightsey Hammock (name used on USGS topo maps) is on a peninsula extending west from US 221 and bounded by Old Field Bay on the west, Peters Bay on the north and Copeland Branch on the south. Most of the peninsula west of the agricultural fields was cleared and planted in slash pine about 20 years ago. The only natural remnants are a few live oaks trees along the sand logging and hunting paths and a small remnant of hardwood hammock dominated by live oak, laurel oak, water oak and pignut hickory with an understory of horse sugar (*Symplocos tinctoria*) at the location of the hunting camp on the point at the northeastern corner of the peninsula on Peters Bay.
ORIGINAL VEGETATION: Live oak, laurel oak, water oak, white oak, swamp chestnut oak, willow oak, pignut hickory, sweetgum, magnolia, spruce pine, loblolly pine/mixed shrubs.
CT: Mixed fire refugial oaks and pines, *Carya glabra* and *Magnolia grandiflora/Symplocos tinctoria-Vaccinium* spp.

5. Wet-Mesic Longleaf Pine Savanna ☼

SOIL SERIES: (shaded in red as a reminder that these moist savannas contained the highest species diversity and were the vegetation communities most dependent upon fire. Without frequent fire they are subject to loss of species diversity and rapid invasion by shrubs and saplings.

Leefield loamy sand Le (LO), LsA (LA) – loamy, siliceous, Arenic Plinthaquic Paleudults, SPD, 1.5-2.5 ☼ ♠

Barth Ba, Bb (LA) sand – sandy, siliceous Plinthaquic Paleudults, SPD, 1.5-2.5 (name no longer used, maybe lumped with Leefield) ☼

Albany sand AdA (LO) – loamy, siliceous, Grossarenic Paleudults, SPD, 1-2.5 ☼

Olustee sand Oa (LA & LO) – sandy, siliceous, Ultic Albaquods PD, 1.5-2.5 ☼ ⌂

Alapaha loamy sand At (LA) – loamy, siliceous Arenic Plinthic Paleudults, PD, 0-1 ☼ ⌂ ♠

Mascotte sand Mn (LA & LO) – sandy, siliceous Ultic Haplaquods, PD, 0-1 ☼ ⌂ ♠

Pelham loamy sand Pe (LO), Pl (LA) – loamy, siliceous, Arenic Paleaquults, PD, 0.5-1.5 ☼ ⌂ ♠

ORIGINAL VEGETATION: Longleaf pine with occasional slash pine or pond pine in wet microsites/wiregrass-diverse mesic savanna graminoids and forbs
CT: *Pinus palustris/Aristida beyrichiana*-very diverse mesic savanna graminoids and forbs
CT: *Pinus palustris-Pinus serotina-Pinus elliottii/Aristida beyrichiana*-very diverse mesic savanna graminoids and forbs
CT: *Pinus palustris/Muhlenbergia expansa*-very diverse mesic savanna graminoids and forbs

In general, species diversity in the herb layer increases as we proceed down the moisture gradient from dry to wet. Under a frequent fire regime a number of other grass species, including little bluestem (*Schizachyrium scoparium*), and possibly other native grasses such as big bluestem (*Andropogon gerardii*) and Indian grass (*Sorghastrum nutans or S. secundum*) may have been locally dominant depending upon subtle differences in soil moisture and texture. With frequent fire the wetter parts of these moist soils provide habitat for species of pitcher plants, other insectivorous plants and many rare savanna plant species including members of the orchid and lily families. These would have been the most species-rich communities at Grand Bay.

Figure 21. Olustee sand at Fort Stewart under a 1-3 year fire regime.

Figure 22. Annually burned Mascotte series at Fort Stewart. Dominant grass at this location is *Muhlenbergia expansa*.

Figure 23. Fire suppressed former longleaf pine savanna on Leefield soil with fire recently reintroduced, along Shiner Pond Road just northwest of Shiner Pond. Compare with figures above and Figure 24 below for appearance of moist longleaf pine savannas on soils similar to Leefield loamy sand under a natural fire regime.

Figure 24. Open longleaf pine savanna on the Leefield series under the natural fire frequency for this site of 1-3 years. The two layered structure is typical of frequently burned vegetation with a fire resistant tree (all longleaf pine except for an occasional slash pine in moister microsites) over a species-rich grass-forb ground cover. This type of landscape was frequently described by travelers in Colonial times. Note longleaf pine reproduction despite the very high fire frequency. An exemplary site on Fort Stewart.

INSECTIVOROUS PLANTS AND OTHER FIRE FREQUENCY INDICATOR SPECIES of wet longleaf pine and mixed pine savannas and bogs.

Most of the insectivorous plants in the South are useful indicators of past fire frequencies and remnant individuals or populations provide some information on the original fire regimes. Two populations of trumpets (*Sarracenia flava*) are known to remain on Grand Bay. One is on the triangular island of mineral soils known locally as "Doughboy Bay" just northwest of the berm and gravel road on Grand Bay Creek near the education center. The other is on soils mapped as Rutledge and Portsmouth in a several hundred acre opening just northeast of the northernmost part of Shiner Pond. This population is on shallowly-impounded soils with a post-impoundment muck and floating mat accumulation. The plants could have been native under the original fire regime at this same spot, formerly in fire-maintained bogs and now supported on floating mats where their original habitat was flooded, or may have seeded in from former populations in other boggy sloughs in the area. There are also scattered populations of hooded pitcher plant (*Sarracenia minor*) in a number of places on the low wet mineral soils fringing wetlands in the Grand Bay and Grand Bay Creek vicinity. One area of small populations occurs on the low mineral soils) mostly mapped as Alapaha loamy sand and Mascotte sand just north of Alapaha Creek and west of US 221 (Tip Hon, pers. comm. 2006). This area appears as fire class C (1-6 year natural fire frequency) on the GIS map of original fire regimes of Grand Bay/Banks Lake.

Moist pockets in the Olustee, Alapaha, Pelham and Mascotte soils (especially the wetter phase of the Pelham) would have been the principle original habitat for sun-loving, frequent fire species such yellow trumpets (*Sarracenia flava*) and hooded pitcher plant (*Sarracenia minor*) as well as numerous other grasses, sedges and forbs endemic to wet savannas.

Figure 25 A. Hooded pitcher plant (*Sarracenia minor*) on the wet phase of Pelham soil thriving under an annual fire regime (Fort Stewart, Georgia). Figure 25 B. Yellow trumpets (*Sarracenia flava*) on a wet, boggy soil under a two-year fire regime (Ft. Bragg, North Carolina). Both are shade-intolerant species of wet savannas and bogs. *Sarracenia flava* is an excellent fire frequency indicator for the highest fire frequency class: a 1-3 year interval in required to prevent encroachment by shrubs and tree saplings. Both are fire frequency indicator species for an original 1-3 year fire frequency although *S. minor* is a little more shade tolerant and may persist longer without fire than trumpets.

6. Wet Mixed Pine Savanna ⌂

SOIL SERIES: Not limited to a particular series.

ORIGINAL VEGETATION: Longleaf pine and pond pine with occasional slash pine and loblolly in wet microsites. Patches of mixed pine savanna would have been found in portions of the landscape that burned fairly often but were partially fire sheltered, These situations were found on the parts of the Olustee, Alapaha, Mascotte and Pelham soils. On the wetter patches of these soils there may have been local patches of slash pine savanna and flatwoods with saw palmetto:

CT: *Pinus palustris-Pinus serotina*/diverse wet-mesic savanna graminoids and forbs

CT: *Pinus palustris-Pinus elliottii-Pinus serotina-Pinus taeda*/*Serenoa repens*-diverse wet mesic graminoids and forbs

Figure 26. Natural mixed pine savanna with longleaf, slash, pond pine and loblolly on moist Alapaha sands along Shiner Pond Road northwest of Shiner Pond. Fire suppressed with fire recently reintroduced. While overgrown with shrubs, many of the grassy savanna species are still hanging on. Wiregrass, found under a broad range of fire regimes, is a less specific fire frequency indicator than species like *Sarracenia flava.* but on moist soils like the Alapaha, it narrows to a indicate a 1to 6 year fire frequency. All wiregrass has been eliminated from the site by long fire suppression but a few clumps occur along the next dirt road intersection (in Lowndes County) to the west and could be used as a source for reintroduction. This specific location, readily approached by fire from the southwest, occurs in the B (1-4 year) range on the presettlement fire frequency map.

7. Pine Flats (loblolly and slash pine with wet bottomland hardwoods) ▲▼ ■ ♦

ORIGINAL VEGETATION: Of the 48 trees listed in Old Field Bay, 40 were pines (Table 6 above). Considering the original influence of fire and the remnant trees in wet bottomlands today these appear to have been a mixture of slash and loblolly pine varying locally with access by fire. There were only 3 bays and 5 gums reported. Sweetgum, swamp black gum and sweet bay are all common on the flats remaining above water level.

SOIL SERIES:

Unknown, inundated soils. Judging from the clayey bottom texture in places, some were likely to be unique to Lowndes and Lanier counties.

CT: Pinus taeda-Liquidambar styraciflua-Magnolia virginiana-mixed bottomland oaks

CT: Pinus elliottii-Nyssa biflora

CT: Nyssa biflora/Saururus cernuus

Figure 27. Fallen white oak (*Quercus alba*) on moist flats with loblolly pine and magnolia below the western upland scarp on the Ben Strickland farm. These flats, found around the northwestern and northern curve of Old Field Bay would have been dry enough to farm in the pre-impoundment situation. Soils are mapped (inappropriately) as Rutledge. The original Old Field bay-Banks lake bottoms may have had two or three bottomland soils not found anywhere else in the two counties.

8. Small Lime Sink Depression Ponds, Sloughs and Pond Margins, intermittently flooded ¶

ORIGINAL VEGETATION: Pond pine, swamp black gum, cypress, loblolly pine, wetland graminoids.

SOIL SERIES:

Pelham loamy sand (when in round lime sink depressions) Pe (LO), Pl (LA) – loamy, siliceous, Arenic Paleaquults, PD, 0.5-1.5 ¶ ☼ ⌂

Portsmouth loam Por (LA)– fine-loamy over sandy or sandy-skeletal Typic Umbraquults, VPD, +1-1 ¶
Grady sandy loam, Gr (LO), Grd (LA) – clayey, kaolinitic Typic Paleaquults, PD, +2-1 ¶
CT: *Pinus elliottii-Nyssa biflora*/diverse wet mesic savanna graminoids and forbs
CT: *Taxodium ascendens-Nyssa biflora*/mixed wetland shrubs/Nymphaea odorata
CT: *Taxodium ascendens*/diverse emergent graminoids
CT: *Pinus elliottii/Carex walteriana*-mixed wetland graminoids (Pelham soils)
CT: *Pinus serotina/Arundinaria gigantea* (Pelham soils)
CT: *Pinus serotina-Pinus palustris*/very diverse wet savanna graminoids and forbs, including pitcher plants (Pelham soils)

Natural examples of vegetation on the seasonally flooded Portsmouth soils (Por) can be seen in Monks Pond along U.S, 221 and in a few other shallow bays. Where Por is mapped in the impounded areas, such as the unit just north of Shiner Pond, it is an impoundment artifact with hydrology and soil unlike the true Portsmouth soils.

To complicate matters, in Lanier County, Pelham soils have two symbols Pl and Pls and three major vegetation types may be found on soils mapped as Pelham. Pelham is treated as a wetter soil in Lanier than in more modern soil surveys where it tends to be a wet longleaf pine savanna type, sometimes mixed with slash pine and a few pond cypress. The soil label Pls is used for the phase in linear drains and is generally wetter than true Pelham soils. In fire accessible flats, more typical Pelham savannas would have been found. The third category are the numerous lime sinks mapped as Pelham, where the soil name serves as a sort of catch-all. The wetter of these have stands of pond cypress or swamp black gum with water lilies with a long hydroperiod and should be considered a different soil series.

Figure 28. Slash pine/*Carex walteriana* in a slough at Fort Stewart. This scene would have been characteristic of some of the frequently burned portions of the wetter Pelham and Bayboro soils at Grand Bay under the natural fire regime. With reduction or exclusion of fire, most sites today have succeeded to heavy, multistoried woody cover with loss of much of the original ground cover . Overall, the original Grand Bay wetland complex would have been a much more grassy landscape.

The variety of soils mapped as Pelham supported the greatest variety of vegetation community types on the natural area. There is a stand of pond pine that may have originally been pond pine/canebrake on the band of Pelham soil just north of the ordnance storage area. Outside of Dudley's Hammock this was the next most important old growth stand seen in the area.

9. Clay-based Bays

ORIGINAL VEGETATION: Dominated by emergent graminoids with scattered slash pine, peripheral swamp black gum and occasional pond cypress.

SOIL SERIES:

Bayboro loam Bm (LO) – clayey, mixed, Umbric Paleaquults, VPD, 0-1 ♦ ¶ ■

Some areas mapped as Pelham loamy sand Pe (LO), Pl (LA) – loamy, siliceous, Arenic Paleaquults, PD, 0.5-1.5 ¶ ☼ ⌂ ♠

CT: Diverse emergent clay-based Carolina bay graminoids
CT: *Pinus elliottii*/diverse emergent clay-based bay graminoids
CT: *Pinus elliottii-Nyssa biflora*/hydric graminoids and forbs (margins)
CT: *Nymphaea odorata*-diverse submersed and emersed freshwater aquatics

10. Small Stream Swamp and Pyrophytic Wetland Mosaic Structured by Fire and Beaver ♦

ORIGINAL VEGETATION: mosaic elements include swamp black gum, pond cypress, wet hardwood forest, hardwood/canebrake, pond pine/canebrake, pocosin, beaver ponds and freshwater marsh created by beaver).

SOIL SERIES:

Johnston loam Jo (LO) – coarse-loamy, siliceous, acid, Cumulic Humaquepts, VPD, +1, 1.5 ♦

Johnston-Osier-Bibb mosaic Job (LA) ♦:

Johnston loam, coarse-loamy, siliceous, acid, Cumulic Humaquepts, VPD, +1, 1.5
Osier loamy fine sand, siliceous, Typic Psammaquents, PD, 0-1
Bibb fine sandy loam, coarse-loamy, siliceous, acid, Typic Fluvaquents, PD, 0.5-1.5

Pelham "low terrace" Pls (is not the true Pelham series which is drier. Pls is mapped in drains: modern taxonomy would likely classify this as the Ellabelle or a similar series wetter than Pelham, VPD, +1, 0.5 ♦

CT: Nyssa biflora
CT: Pinus elliottii-Magnolia virginiana-Nyssa biflora/mixed swamp shrubs
CT: Pinus elliottii/Arundinaria gigantea
CT: Pinus elliottii-Carex walteriana-mixed graminoids
CT: Pinus serotina/bay-gall shrubs with stature kept low by frequent fire
CT: Pinus serotina/Arundinaria gigantea
CT: Taxodium ascendens
CT: Diverse submersed and emersed aquatic and wetland plants of beaver impoundments.

Figure 29. Large sweet bay (*Magnolia virginiana*) in a small drain leading into Grand Bay. Some such stands originated from fire suppression in former slash pine/bay-galls maintained by fire.

Figure 30. Nearly pure stand of swamp black gum with scattered pond cypress in Grand Bay Creek bottomland west of US 221.

11. Slash Pine, Swamp Black Gum, Pond Cypress, Sweet Bay, Flats and Wetland Complex ■

ORIGINAL VEGETATION: Nyssa biflora, Magnolia virginiana, Pinus elliottii, Taxodium distichum in many of the combinations found in the Pine Flats and Small Stream Swamp communities above.)

MAPPED SOIL SERIES:

Swamp Swa (LA) – no taxonomy given: includes artificially flooded former soils similar to ____, VPD "swamp" likely to have been ___ in original, unimpounded landscape.

Istokpoga complex, Ist (LA) – dysic, hyperthermic Typic Medihemists, VPD, 0-1 (series name is no longer used: see the similar Dasher in Lowndes County). Istokpoga likely to have been ___ in original, unimpounded landscape (named for a natural type in Florida?).

Dasher muck Da (LO) – dysic Typic Medihemists (Haplohemists), VPD, +3-0.5 (an artificial soil type created by intentional flooding). "Dasher" likely to have been mineral soil such as ___ in original, unimpounded landscape.

Banks Lake – originally a bottomland before damming up for a mill pond (so don't show it as water).

ORIGINAL SOIL SERIES:

Unknown but the bottoms have enough topographic variation that there would have been a complex of at least 5 or six soils likely including Rains, Rutlege, Portsmouth and Johnston, as well as some clayey, wet mineral wetland basement soils otherwise not mapped in Lowndes or Lanier counties, such as Ellabelle (Arenic Umbric Paleaquults) and Cape Fear (Typic Umbraquults). In the bottom transects there was no evidence of flooded Terric or Typic Medisaprists (true peats having sapric material of a meter or more).

SOME LIKELY COMMUNITY TYPES IN THE ORIGINAL PATCH MOSAIC:

CT: *Taxodium ascendens*
CT: *Pinus elliottii-Nyssa biflora-Taxodium ascendens*
CT: *Pinus elliottii-Nyssa biflora*
CT*: Pinus elliottii/Carex walteriana*
CT: Bottomland Hardwood Forest (Quercus alba-Quercus nigra-Quercus laurifolia-Magnolia virginiana-Liquidambar styraciflua-Pinus taeda)
CT: Nyssa biflora
CT: Nyssa biflora/Sparganium americanum (Figure 31 below).
CT: Mixed submersed and emersed aquatics of small beaver impoundments along drain channels

Current and Historic Land Cover of Grand Bay-Banks Lake (GBBL) Ecosystem in Lanier and Lowndes Co., GA

Final Report

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April 2006

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INTRODUCTION

Carolina bays, depression wetlands unique to the Atlantic Coastal Plain, are characterized by an elliptical shape, sandy rim and northwest-southeast orientation. Since these wetland features typically lack natural drainages, their vegetation is strongly influenced by hydrology. Woody upland species have the potential to colonize the interiors of Carolina bays following natural (e.g. drought) and artificial water drawdowns (DeSteven and Toner 2004). In addition to providing beneficial wetland functions, Carolina bays are valued for their habitat and species diversity, as well as food web support (Van De Genachte and Cammack 2002; Sharitz 2003).

The Grand Bay-Banks Lake (GBBL) ecosystem, which is considered the second largest freshwater wetland system in Georgia, is composed of several large Carolina bays (TNC 2003). This wetland complex provides habitat for a variety of threatened plants and animals. Two species of particular interest are the Sandhill Crane (*Grus canadensis*) and Round-tailed Muskrat (*Neofiber alleni*). Sandhill Cranes, which are considered imperiled in Georgia (S2 rank), utilize wetlands for foraging and nesting (Pearlstine *et al.* 1995). While these birds appear to prefer marshes and wetland/grassland ecotones (Nesbitt and Williams 1990), Sandhill Cranes also rely on agricultural fields for habitat. Open water and marsh are crucial to the survival of the Round-tailed Muskrat, a vulnerable species (S3 rank) restricted to southern Georgia and Florida (Birkenholz 1963).

This project was undertaken to map current and historic land cover within the GBBL ecosystem, with an emphasis on documenting potential Sandhill Crane and Round-tailed Muskrat habitat. More specifically, we mapped land cover and linear features for the GBBL ecosystem in 1941/1943, 1967, 1983, 1988, 1999, and 2004. Historic dates were chosen to include the initial development of Moody Air Force Base (1941/1943) and the vegetation

response following an extensive peat fire during the winter of 1956-57 (1967). A list of deliverables is presented in Appendix A.

METHODS

The Grand Bay-Banks Lake (GBBL) ecosystem (Fig. 1) includes the following large wetland complexes: Grand Bay, Moody Bay, Rat Bay, Oldfield Bay and Banks Lake. The study area selected for this study is approximately 15,420 hectares and is bounded to the east by U.S. Highway 221, Knights Academy Road to the south, and GA Highway 125 to the west. The northern boundary of the GBBL study area approximately follows U.S. Highway 129, and was chosen to capture agricultural land potentially important for Sandhill Cranes.

Vegetation was mapped using aerial photographs of Lowndes and Lanier counties, Georgia, from 1941/1943 (hereafter, "1940s"), 1967, 1983, 1988, 1993 and 2004 (Table 1). Since the 2004 photographs did not completely cover the study area, we used additional images from 1999 color infrared digital ortho quarter quads (DOQQs) to fill in the gaps. Photographs were interpreted in reverse chronological order, when possible, to aid identification of vegetation from the older images. Land cover polygons were on-screen digitized with ArcMap. Linear features, defined here as roads and hydrological modifications (e.g. ditches), were mapped as separate feature classes for all years of interest. Due to size constraints, data were stored in three separate personal geodatabases: "GB_BL_Pre-1980s" (1940s and 1967), "GB_BL_1980s" (1983 and 1988), and "GB_BL_Recent" (1993 and 2004).

We initially attempted to map vegetation at the ecological systems level, however, there were a couple of setbacks. First, there were sometimes multiple systems that could describe one land cover class, such as scrub/shrub (CES203.505, CES203.384, CES203.262, or CES203.252). In addition, there were examples where the various associations for an ecological system could

be attributed to two different classes. For instance, Atlantic Coastal Plain Southern Depression Pondshore (CES203.262) had some associations that described herbaceous/marsh (e.g. CEGL004475) and others that fit evergreen shrub (e.g. CEGL003844). Overall, we felt that we could not map to this level of detail solely by photo interpretation.

Instead, we modified the Georgia GAP land cover classification system to focus on wetland classes as well as ones that represented land use in areas surrounding the GBBL ecosystem (Table 2); see Appendix A for more information on an Excel spreadsheet with potential ecological systems and associations for this area. When appropriate, modifiers were added to certain classes to provide additional information (e.g. Cypress-Gum Swamp – Riparian). Several land cover classes were eventually merged for data analysis. All bottomland hardwood, cypress-gum swamp and evergreen forested wetland classes were combined into "Forested Wetland." Clearcut and clearcut wetland were collapsed into one "Clearcut" class, and mixed forest and deciduous forest were reclassified as "Forest". Since isolated wetlands had already been individually mapped within potential pine flatwoods, we decided to include longleaf pine stands in the more general "Pine Plantation" class. Finally, we merged open marsh, which was only used within Grand Bay, and herbaceous/marsh into one "Herbaceous/Marsh" class, except when noted.

The total area of each land cover class was calculated in hectares (ha), acres and percentages for each year. Area was initially calculated in acres and then converted into hectares by a factor of 0.405. We also evaluated land cover in terms of management unit (ownership) using the 2004 land cover data. For each land owner, we calculated the percentage of a given class on their property as well as an overall percentage, which is the ratio of a land cover class within a management unit relative to the total area of the class in the entire GBBL study area.

All land cover classifications were converted into 50 ft raster grids and assessed for spatial and temporal changes. One series of analyses focused on changes within several wetland classes (open water, herbaceous/marsh, forested wetland) throughout the entire GBBL study area for each time period (1940s-1967, 1967-1983, 1983-1988, 1988-1993, 1993-2004). A more in-depth evaluation of vegetation changes within the four main Carolina bays (Grand Bay, Moody Bay, Rat Bay, Oldfield Bay) was also performed using the following methods. Since Grand Bay and Oldfield Bay both have relatively intact, forested rims, we assessed only the changes within the interiors of these wetlands over time. For our change analysis of Grand Bay, we differentiated between open marsh and herbaceous/marsh because these were the two most dynamic vegetation classes for this area. We did not perform a change analysis for Grand Bay from 1940s-1967 because the distinction between the two herbaceous/marsh types could not be made with the 1940s imagery. Moody Bay and Rat Bay, however, lack the classic elliptical shape associated with Carolina bays, making it hard to objectively determine their boundaries. To address this problem, we expanded our outlines of Moody Bay and Rat Bay to include some adjacent areas that appeared to be connected to these wetlands at an earlier point in time. While the results of all of these analyses are presented in tables, only key changes were mapped and included in this report.

RESULTS

General Trends

Figures 2(a-f) and 3(a-f) depict land cover and linear features, respectively, within the Grand Bay-Banks Lake (GBBL) ecosystem over the past 60 years. There are currently 254.2 miles of linear features, including roads and hydrological modifications, within this region (Table 4).

Since the 1940s, there has been a net reduction in open water (-1.1%), herbaceous/marsh (-3.8%), and forested wetland (-3.6%) within the GBBL study area (Table 3a-b; Fig. 5). Herbaceous/marsh experienced the largest reduction in size during 1967-1983 (279 ha) and 1988-1993 (337 ha). Another wetland vegetation type, scrub/shrub, has increased over time, especially between 1967 and 1983. While agriculture has historically been the primary land use surrounding GBBL, the number of hectares of agricultural fields has been decreasing since the late 1980s. Pine plantations, however, have steadily increased in size within the past 60 years. Finally, the percentage of urban land cover, which includes the activities of Moody AFB, has doubled since the 1940s. Urbanization has especially increased on land adjacent to Grand Bay and a riparian area in the northwest corner of the GBBL study area (Fig 2f). Most recently, we observed a new housing development being built directly across from the northern rim of Oldfield Bay (Fig. 4).

The composition of each owner’s property within the GBBL study area in 2004 was unique (Table 5a-f; Fig 6a-f). All land owners had some percentage (13.7 - 60.2%) of forested wetlands. Herbaceous/marsh was a large component of TNC (51%), GDNR (28%), and USFWS (18.9%) property. Open water, predominately from Banks Lake, constituted over a fifth of USFWS land cover. The majority of urban land was on Moody AFB and private property. While the only mapped example of an evergreen hammock occurred on Moody AFB, there appears to be a similar—but smaller and more disturbed—community along the northern rim of Oldfield Bay owned by DOT (T. Hon, pers. comm.).

These ownership trends were also evaluated within the context of the entire GBBL study area (Fig 7a-d). Not surprisingly, the majority of open water within the GBBL study area was owned and managed by USFWS. Over half of the 1388 hectares of scrub/shrub occurred on

Moody AFB, with all other land owners typically having fewer than 250 ha each. Finally, 35.6% of forested wetlands within the GBBL study area were located on private property.

Change Analysis – Wetland Vegetation

Open water within the GBBL ecosystem has either remained the same or transitioned into herbaceous/marsh. This conversion has become increasingly prominent in the past 20 years with almost 25% of open water transitioning into herbaceous/marsh from 1993-2004 (Table 6a). Most of this change appears to be occurring in Eagle's Neck, the aquatic area in the northeastern section of Oldfield Bay, and to a lesser degree within Rat Bay (Fig 8a). There is also some evidence of open water areas transitioning into forested wetland during 1940s-1967 and 1988-1993. This trend is illustrated in Figure 8b where wetlands near the current GDNR and Moody AFB boundary experienced change between the 1940s and 1967.

A considerable amount of herbaceous/marsh has filled in with woody vegetation over the past 60 years. For most time intervals, at least one-third of existing herbaceous/marsh in the GBBL ecosystem changed into either scrub/shrub or forested wetland (Table 6b). Between 1940s and 1967, the interior of Grand Bay transitioned to forested wetland, especially around the northern rim (Figure 9a). During the same time period, Oldfield Bay vegetation underwent several shifts, which will be discussed in further detail in the next section. Scrub/shrub replaced a fair amount of herbaceous/marsh within Moody Bay and Oldfield Bay from 1967-1983 (Figure 9b).

While forested wetland occasionally shifted to other wetland types, conversion to pine plantations and clearcuts accounted for the most change (Table 6c). Loss was most intense during 1967-1983 and 1993-2004, when 9.5% (349 ha) and 9.4% (337 ha), respectively, of forested wetlands were altered. Sections of the Grand Bay rim were noticeably disturbed from

1967-1983 (Fig 10a) and 1988-1993 (Fig 10b). During 1993-2004, the majority of clearcut wetlands was concentrated on private property east of Oldfield Bay, and included a sizable portion of the Oldfield Bay rim (Fig 10c).

Change Analysis – Carolina bays

With the exception of 1983-1988, the vegetation within Grand Bay appeared to be constantly fluctuating between open marsh and herbaceous/marsh (Fig. 11 a-d). For example, areas that had transitioned from open marsh to herbaceous/marsh between 1988 and 1993 (Fig. 11c), returned to open marsh by 2004 (Fig. 11d). However, this might be partially attributed to different water levels present when the photographs were taken. There were less than 20 ha of forested wetlands in the interior of Grand Bay for all time periods (Table 7a-d).

Herbaceous/marsh within Moody Bay diminished in size from 188 ha in 1967 to a mere 9 ha in 1993 (Table 8a-e). The loss of herbaceous/marsh, which was predominately in the southern half of Moody Bay, was associated with increased shrubby vegetation (Fig. 12 a-e). The large increase in herbaceous/marsh from the 1940s to 1967 (Fig. 12a) is possibly an artifact of the poor quality of the 1940s imagery, where it was hard to distinguish herbaceous/marsh from scrub/shrub in Moody Bay. Forested wetlands within the immediate vicinity of Moody Bay also experienced a lot of change in the past 60 years, especially from 1940s-1967 (Table 8a-e). The conversion of forested wetlands to pine plantation or clearcut was somewhat offset by concurrent changes from scrub/shrub to forested wetland (Fig 13 a-b).

The most change in wetland features within and around Rat Bay occurred in open water and herbaceous/marsh. Overall, the total area of open water and herbaceous/marsh habitat in this region, which is approximately 830 ha, was relatively low (range: 66-88 ha; Table 9a-e). Most of the open water observed in the 1940s had turned into forested wetland by 1967 (Figure 14a).

Since 1988, there has been further loss of open water to forested wetland and herbaceous/marsh within Rat Bay and the adjacent bombing range (Figure 14b). Similarly, areas that were initially herbaceous/marsh in the 1940s transitioned into woody vegetation by 1967 (Figure 15a).

Several substantial vegetation shifts occurred within Oldfield Bay from the 1940s to 1967 (Table 10a; Figure 16). In accordance with a successional trajectory, almost half of existing herbaceous/marsh filled in with scrub/shrub whereas approximately 10% of scrub/shrub developed into forested wetland. However, there were also unusual vegetation changes during this time period. For example, 30.5% of the 413 ha of forested wetlands reverted back to herbaceous/marsh. In subsequent years, the percent cover of scrub/shrub and forested wetland has greatly increased inside Oldfield Bay (Table 10b-e; Figure 17 a-d). During 1988-1993, over two-thirds of the remaining herbaceous/marsh changed to either scrub/shrub or forested wetland. Figure 18 shows an area within Oldfield Bay that is still predominately herbaceous/marsh in 2006 but is noticeably surrounded by scrub/shrub and occasional trees. Finally, as previously noted, the open water in the northeastern portion of Oldfield Bay (Eagle's Neck) has been transitioning into herbaceous/marsh since the late 1980s (Fig 17c-d).

DISCUSSION

Our analyses of current and historic land cover in the Grand Bay-Banks Lake (GBBL) ecosystem suggest that critical wetland habitat for Sandhill Cranes and Round-tailed Muskrats is being lost to succession. This trend is most pronounced within Oldfield Bay where scrub/shrub and forested wetland have consistently increased in area since 1967. Similarly, there is evidence of open water transitioning into herbaceous/marsh during the same time period. Prior to 1967, we documented substantial reversion from woody vegetation to herbaceous/marsh, which can probably be attributed to plant mortality following the fire of 1956-57. Therefore, we

suggest that fire should be included in management strategies to increase open water and herbaceous/marsh within Oldfield Bay. It should also be noted that shrub encroachment is occurring at Grand Bay (A McGee, pers. comm.). Unfortunately, we were unable to discern scrub/shrub vegetation from other forested communities based on the aerial photographs alone.

The conversion of forested wetlands to clearcut, pine plantations and urban land cover also appears to be compromising wetlands in this region. There has been an increase in residential areas and roads adjacent to various wetland features within the GBBL study area. Disturbances to the forested rims of Grand Bay and Oldfield Bay could provide an avenue for increased invasion of woody species into the interiors of these Carolina bays. Additionally, these land cover changes could lead to increased impervious surfaces around the wetlands and, in turn, create new hydrological modifications. Finally, the loss of isolated cypress domes, especially on private property in the eastern section of the GBBL study area, should be of concern because these communities often included patches of open water that were either too small or complicated to map but could feasibly be utilized by Sandhill Cranes.

In general, moderate to high amounts of land cover change could be detected within the GBBL study area for all time periods except from 1983 to 1988. This suggests that significant vegetation change cannot be observed over such a short time span (5 years). It is interesting to note, however, that considerable land cover change occurred during the following five years (1988-1993), including the second largest decrease in herbaceous/marsh area and the initial decline in agricultural cover.

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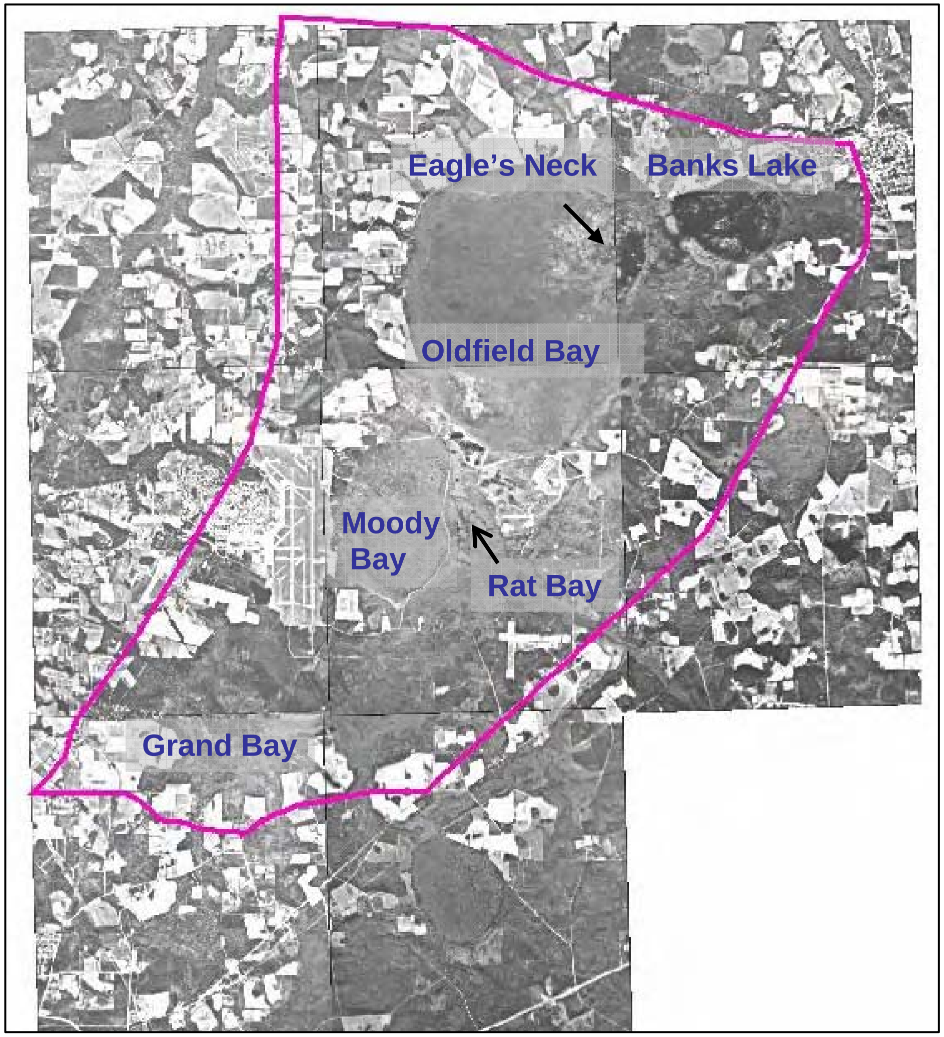

Figure 1. Outline of Grand Bay-Banks Lake ecosystem study area. Imagery is from the 1993 DOQQs.

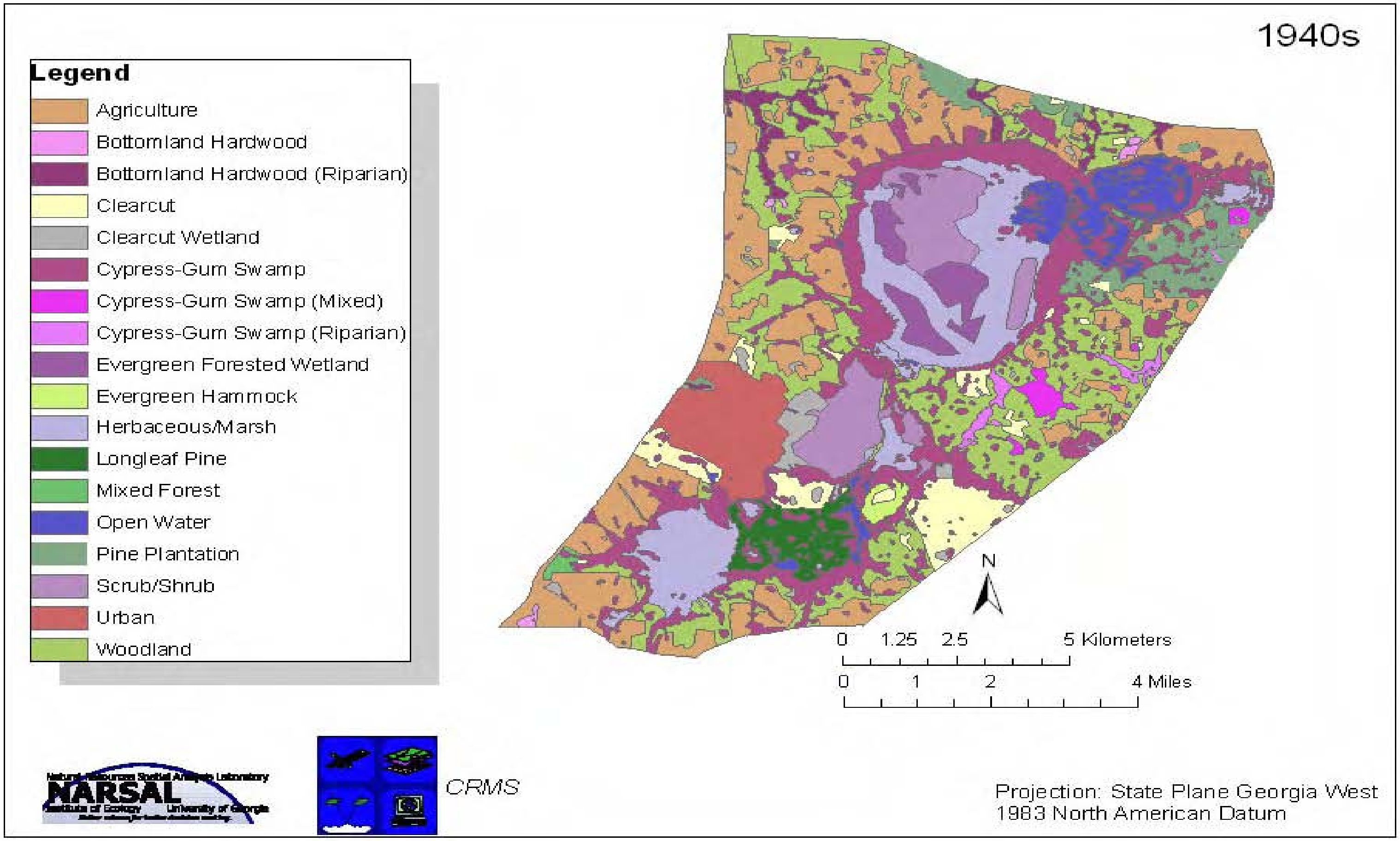

Figure 2a. Grand Bay-Banks Lake (GBB) ecosystem land cover: 1940s.

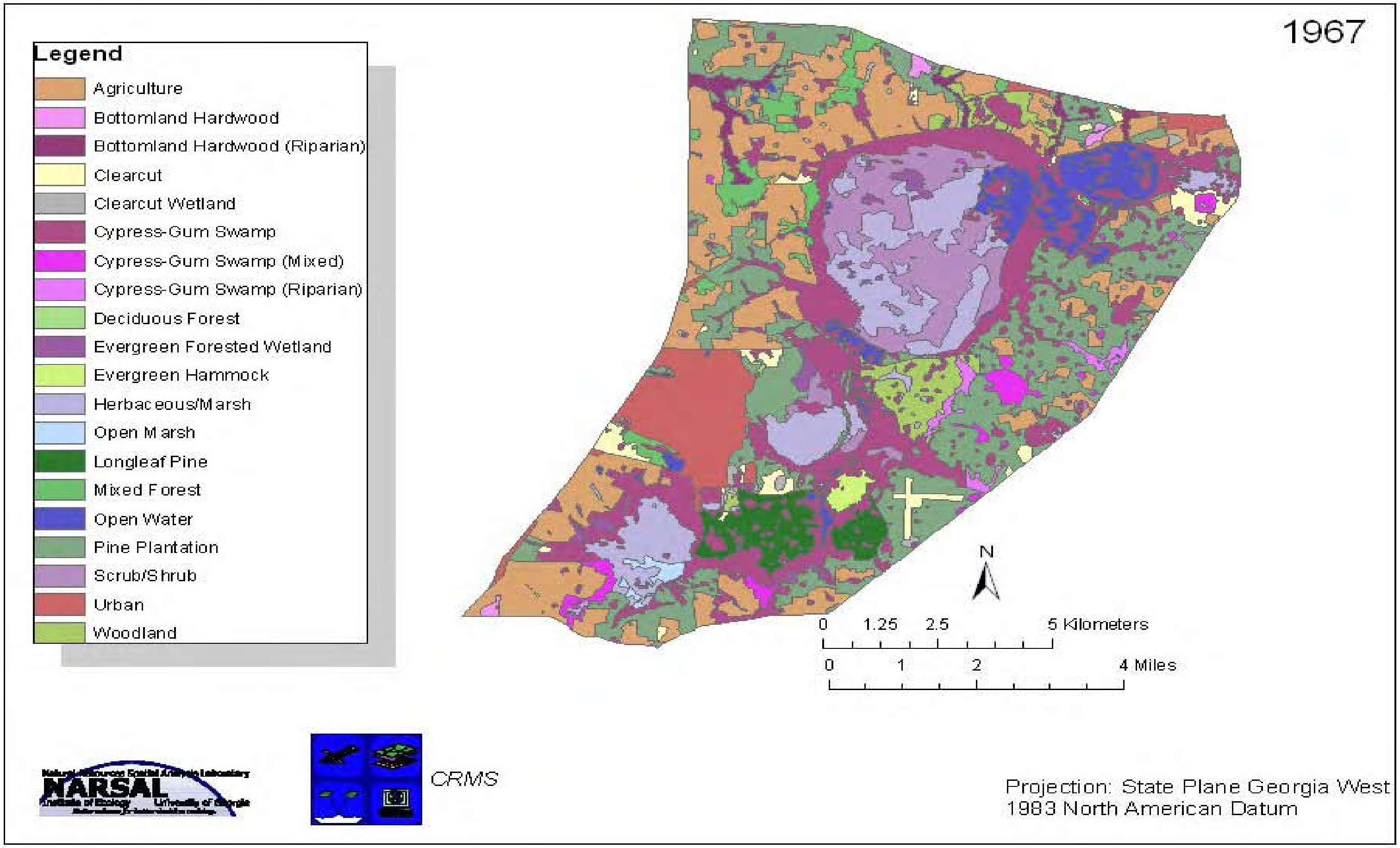

Figure 2b. Grand Bay-Banks Lake (GBBL) ecosystem land cover: 1967.

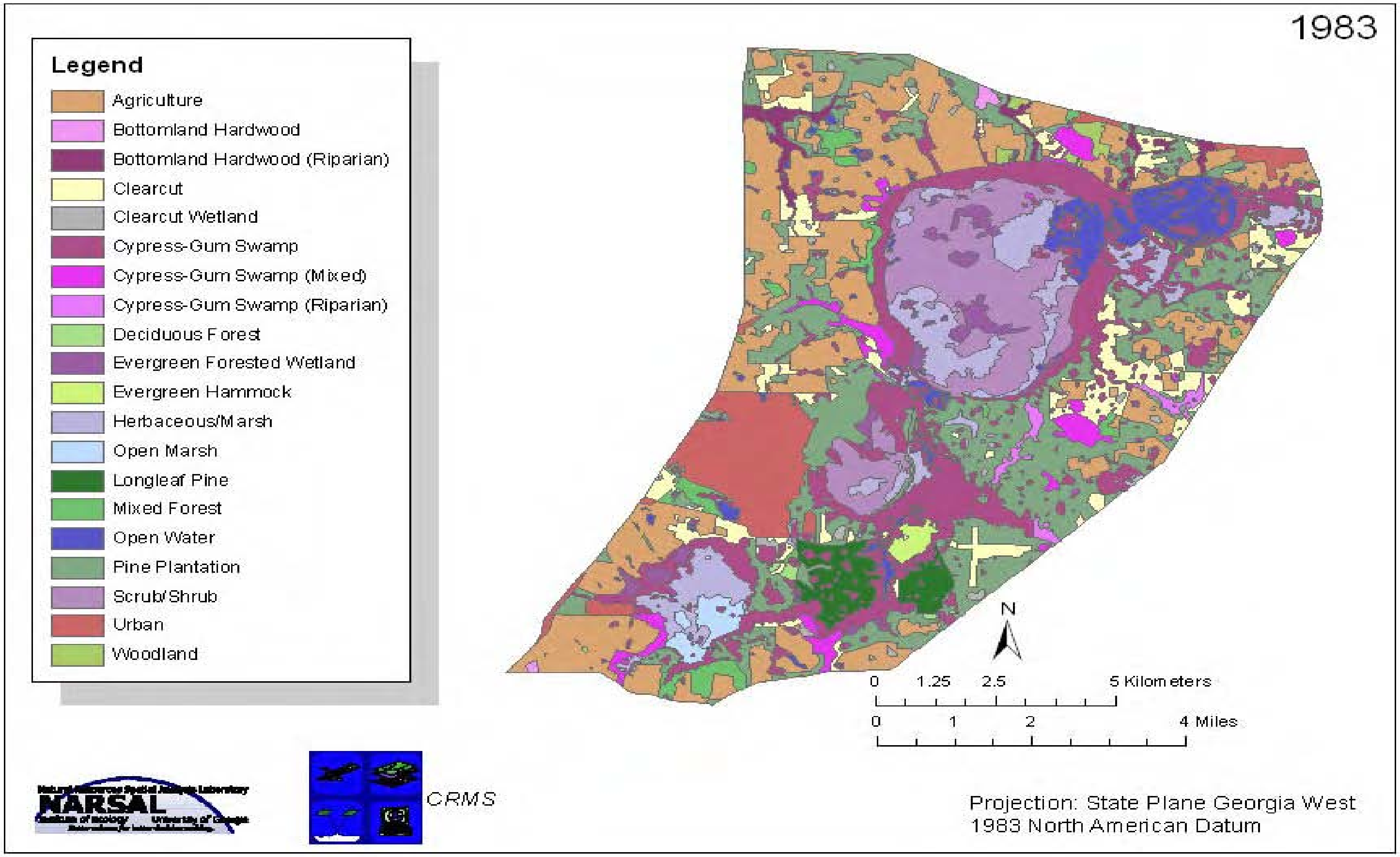

Figure 2c. Grand Bay-Banks Lake (GBBL) ecosystem land cover: 1983.

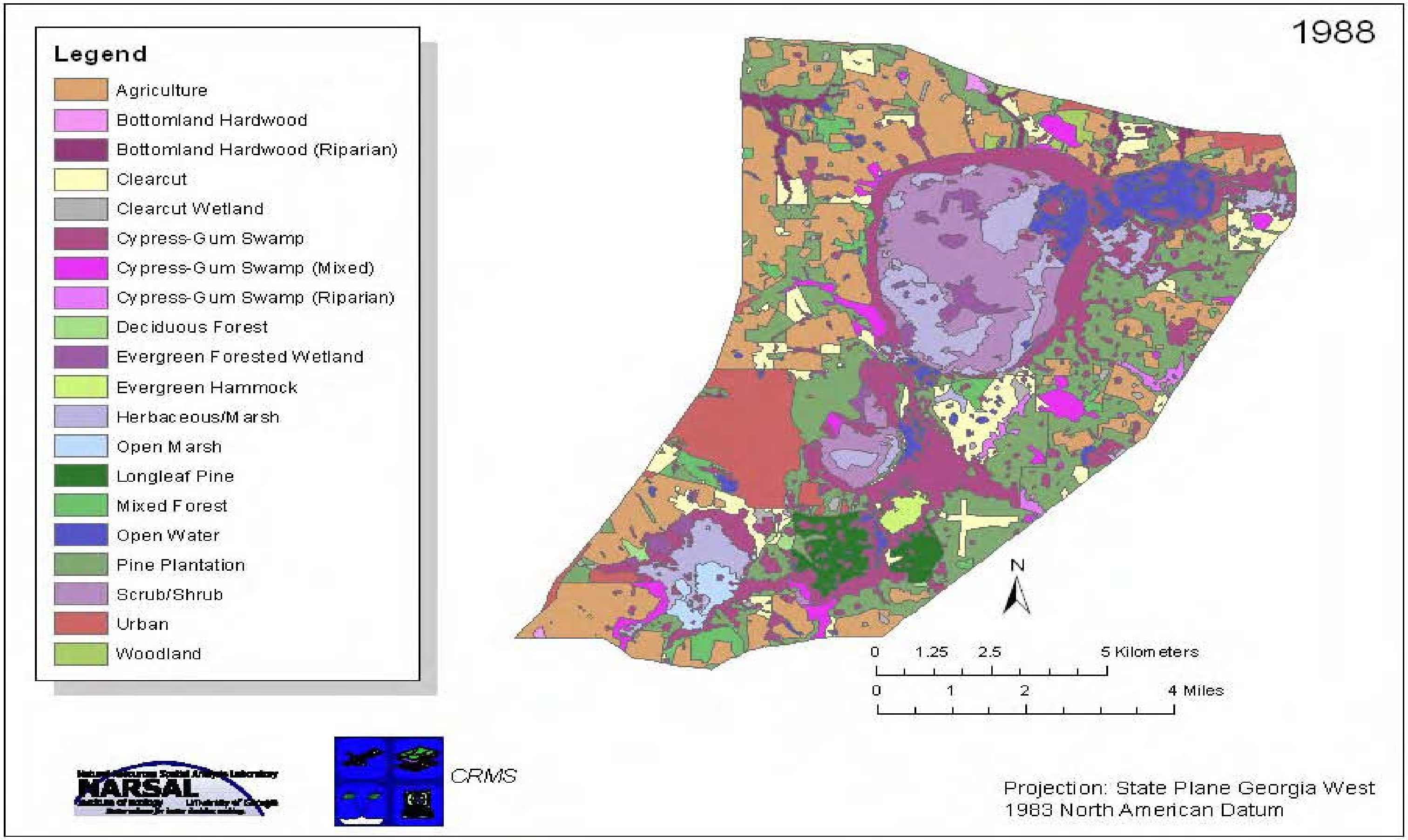

Figure 2d. Grand Bay-Banks Lake (GBBL) ecosystem land cover: 1988.

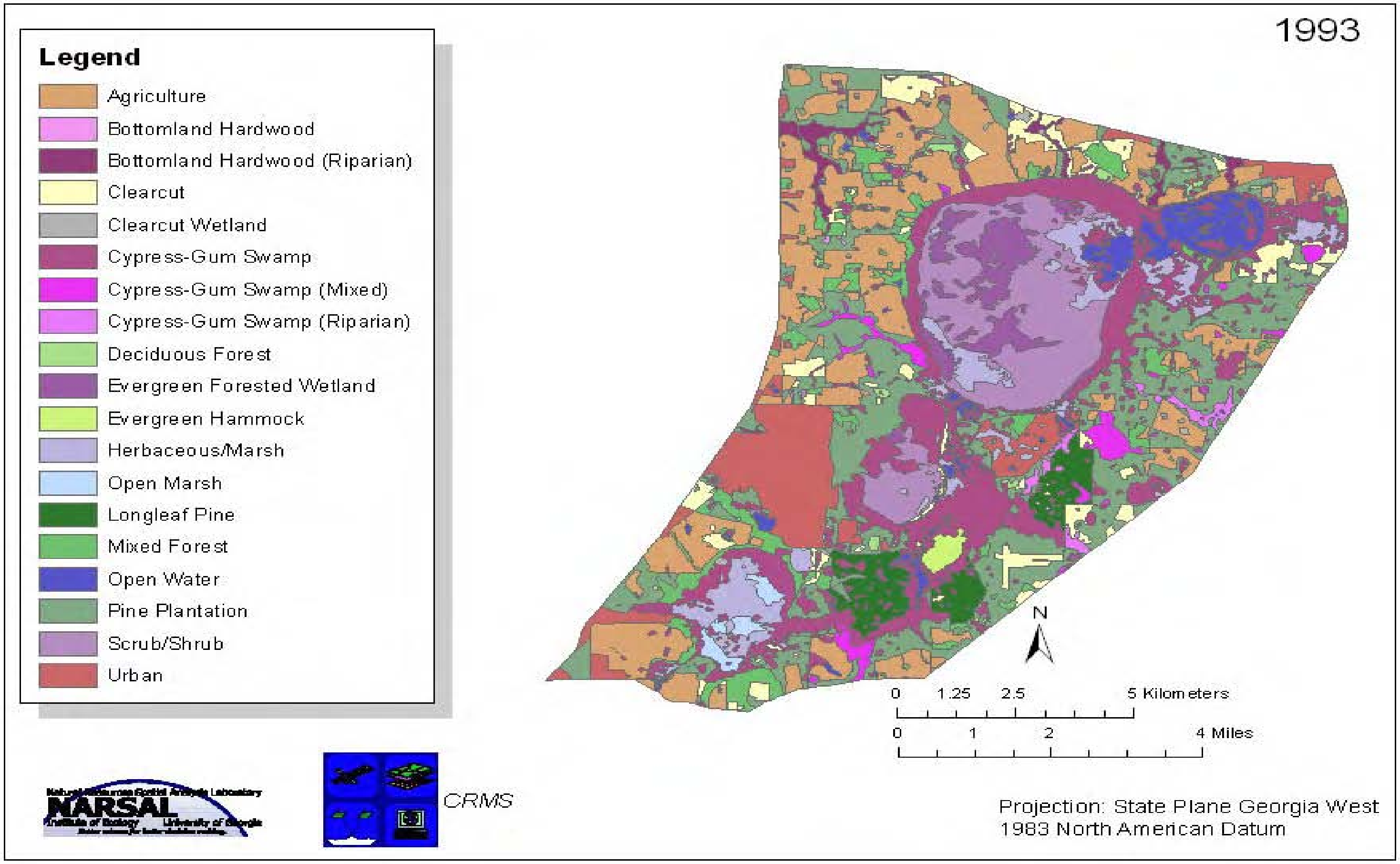

Figure 2e. Grand Bay-Banks Lake (GBBL) ecosystem land cover: 1993.

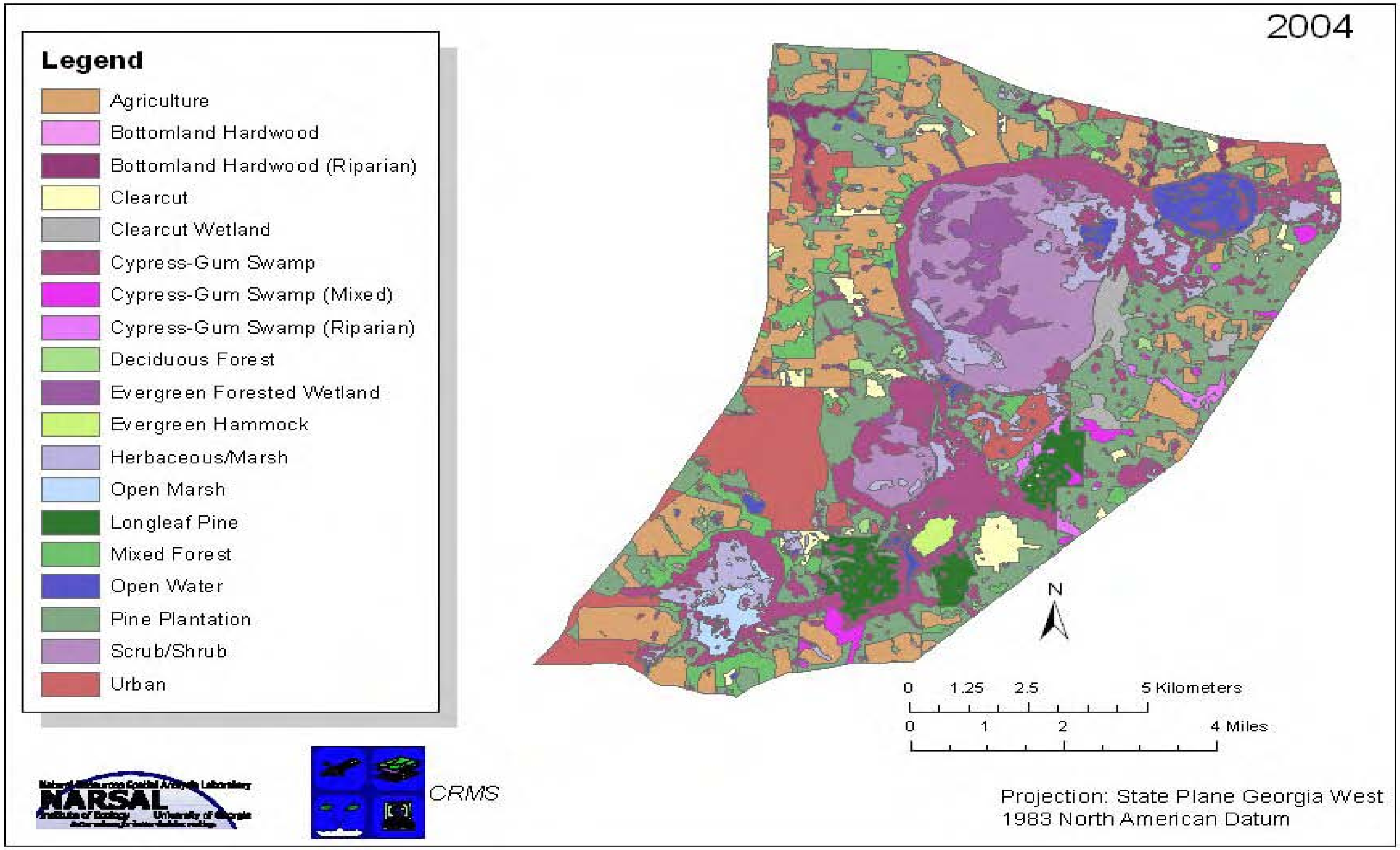

Figure 2f. Grand Bay-Banks Lake (GBBL) ecosystem land cover: 2004.

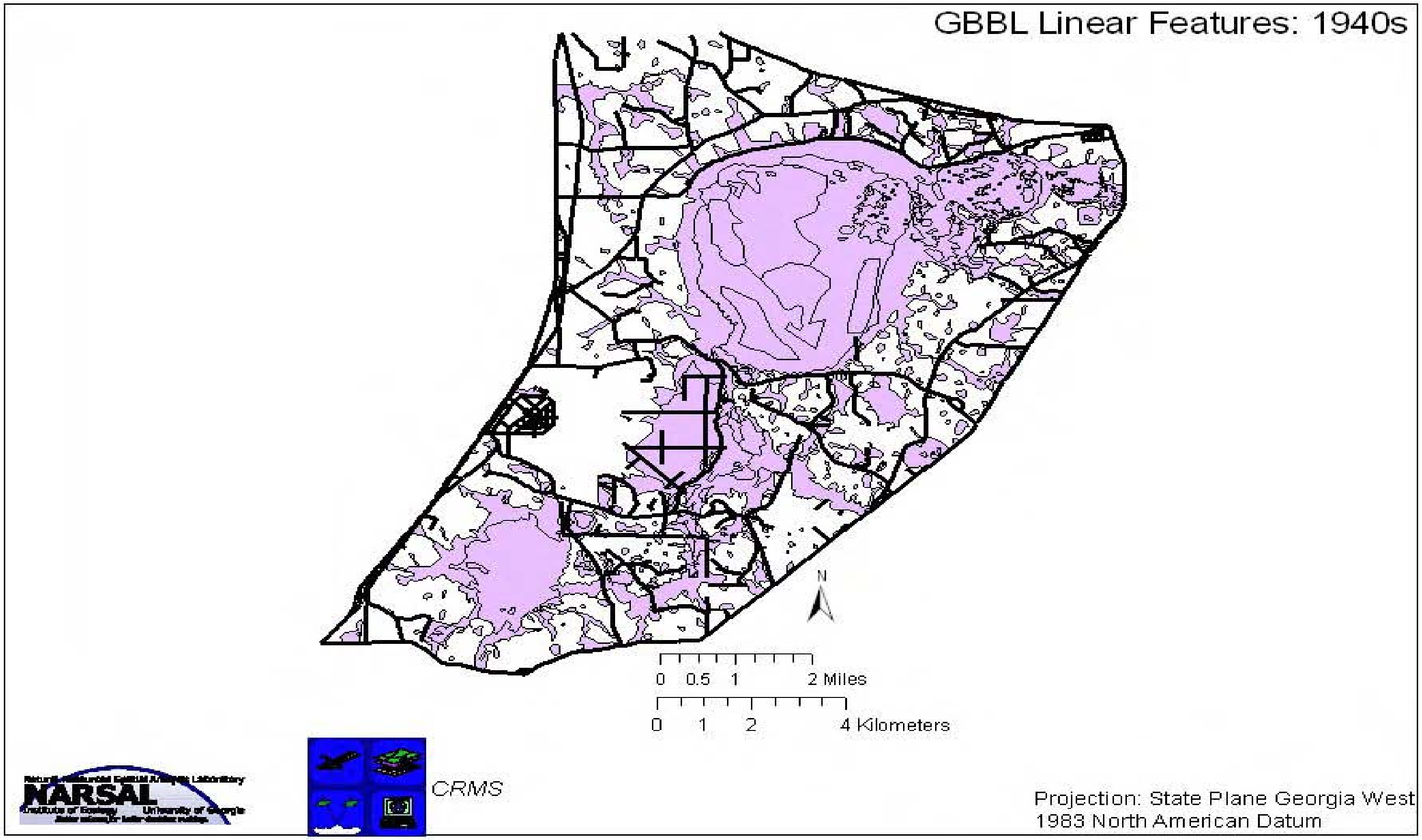

Figure 3a. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 1940s. Polygons represent all wetland classes within GBBL study area at this date.

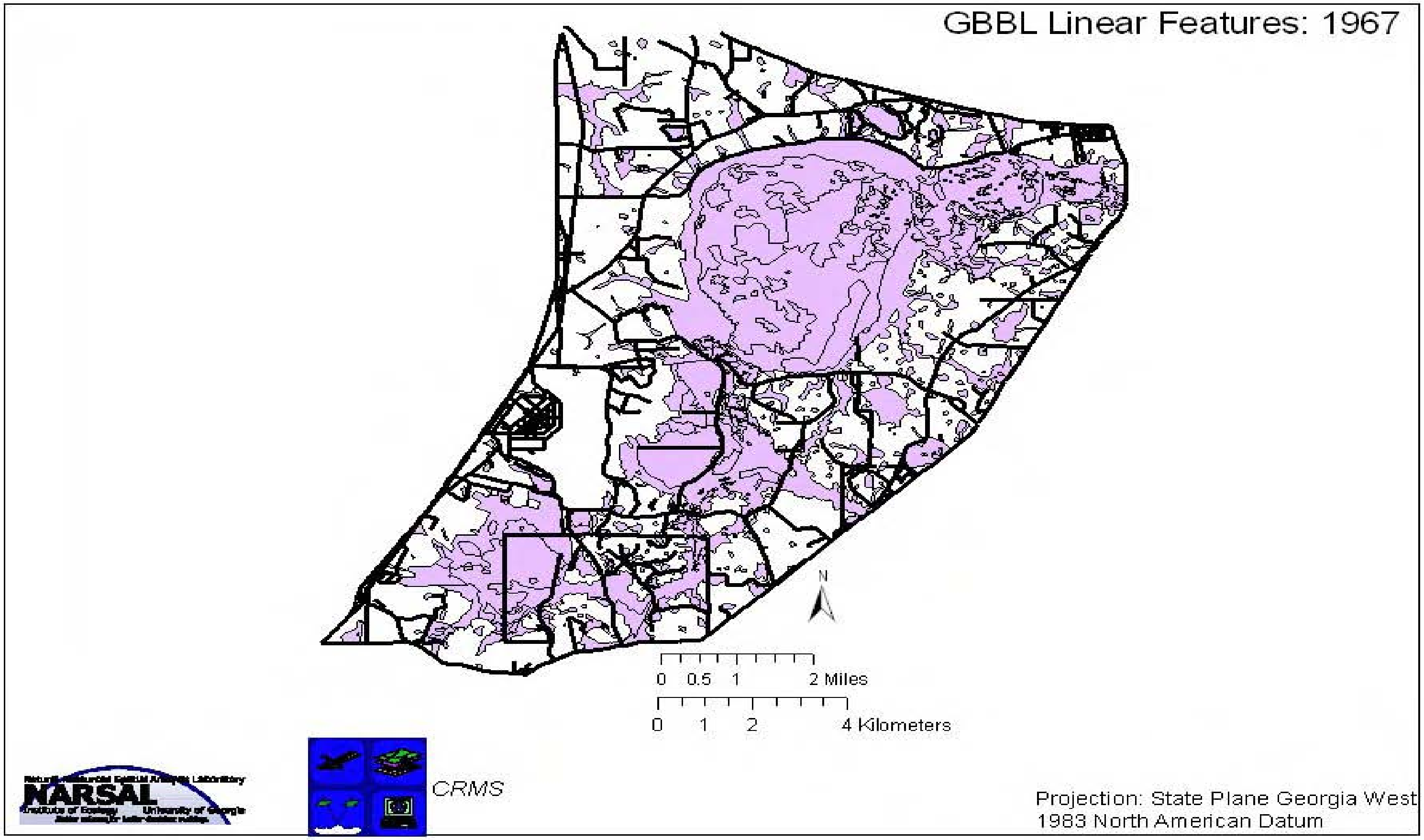

Figure 3b. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 1967. Polygons represent all wetland classes within GBBL study area at this date.

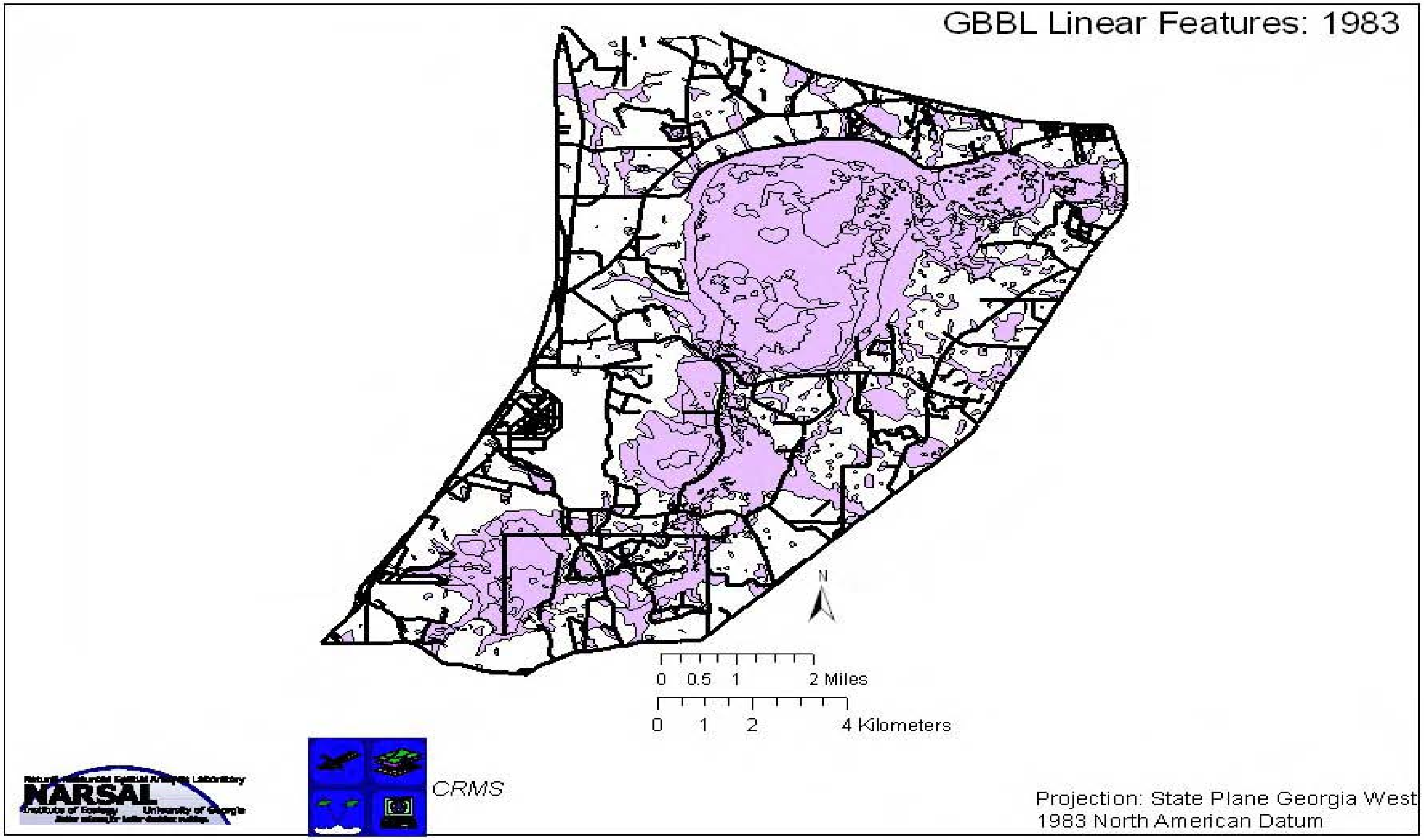

Figure 3c. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 1983. Polygons represent all wetland classes within GBBL study area at this date.

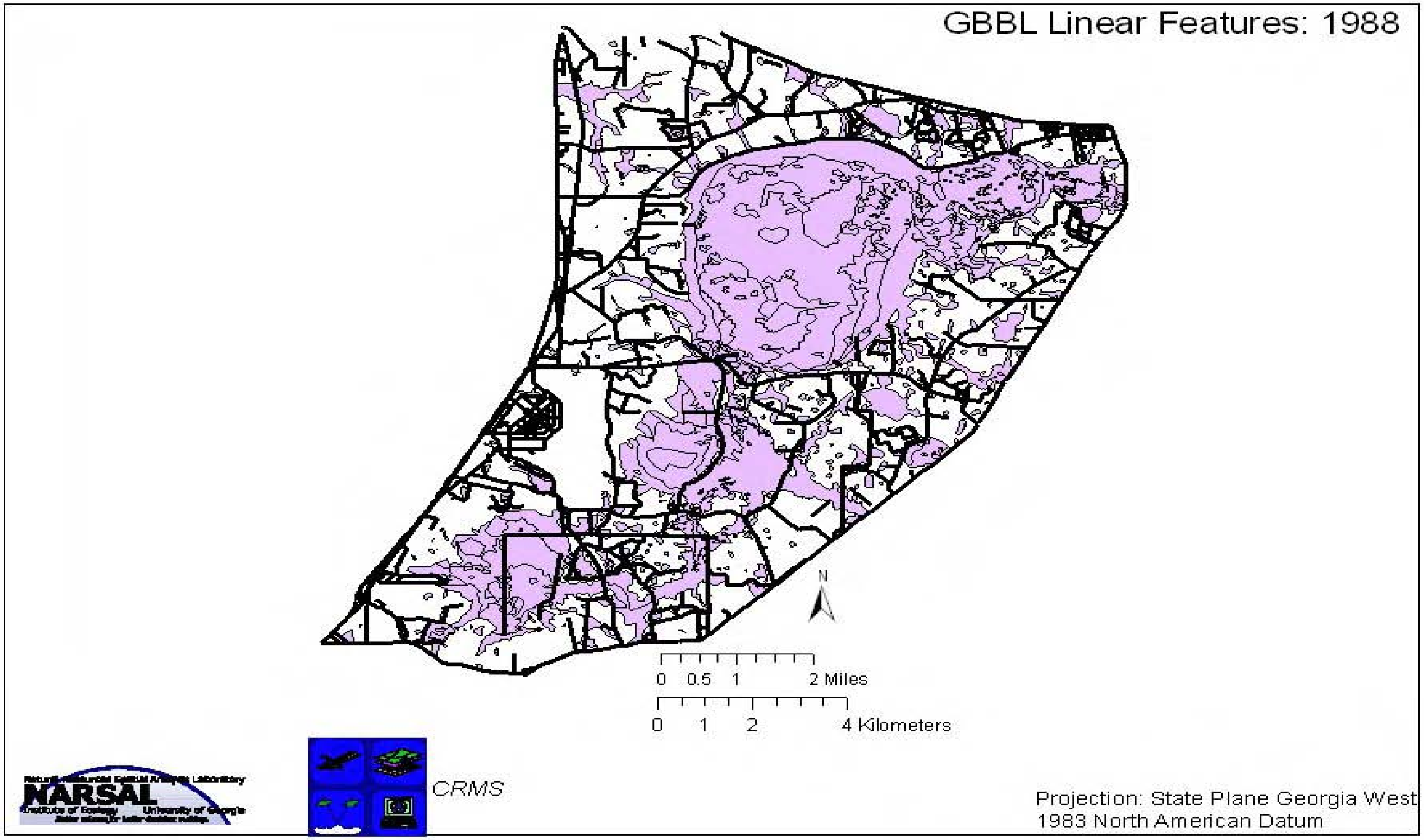

Figure 3d. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 1988. Polygons represent all wetland classes within GBBL study area at this date.

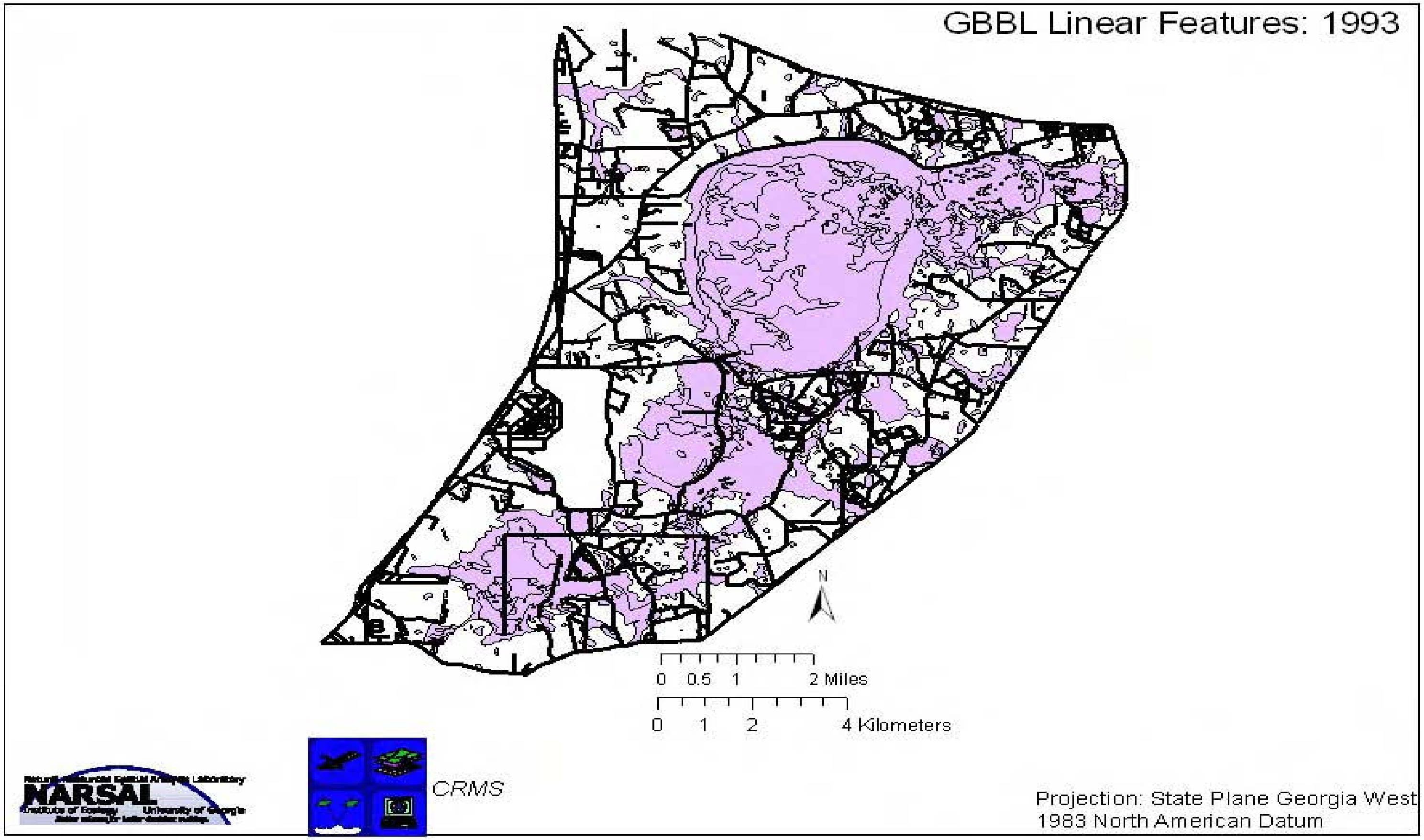

Figure 3e. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 1993. Polygons represent all wetland classes within GBBL study area at this date.

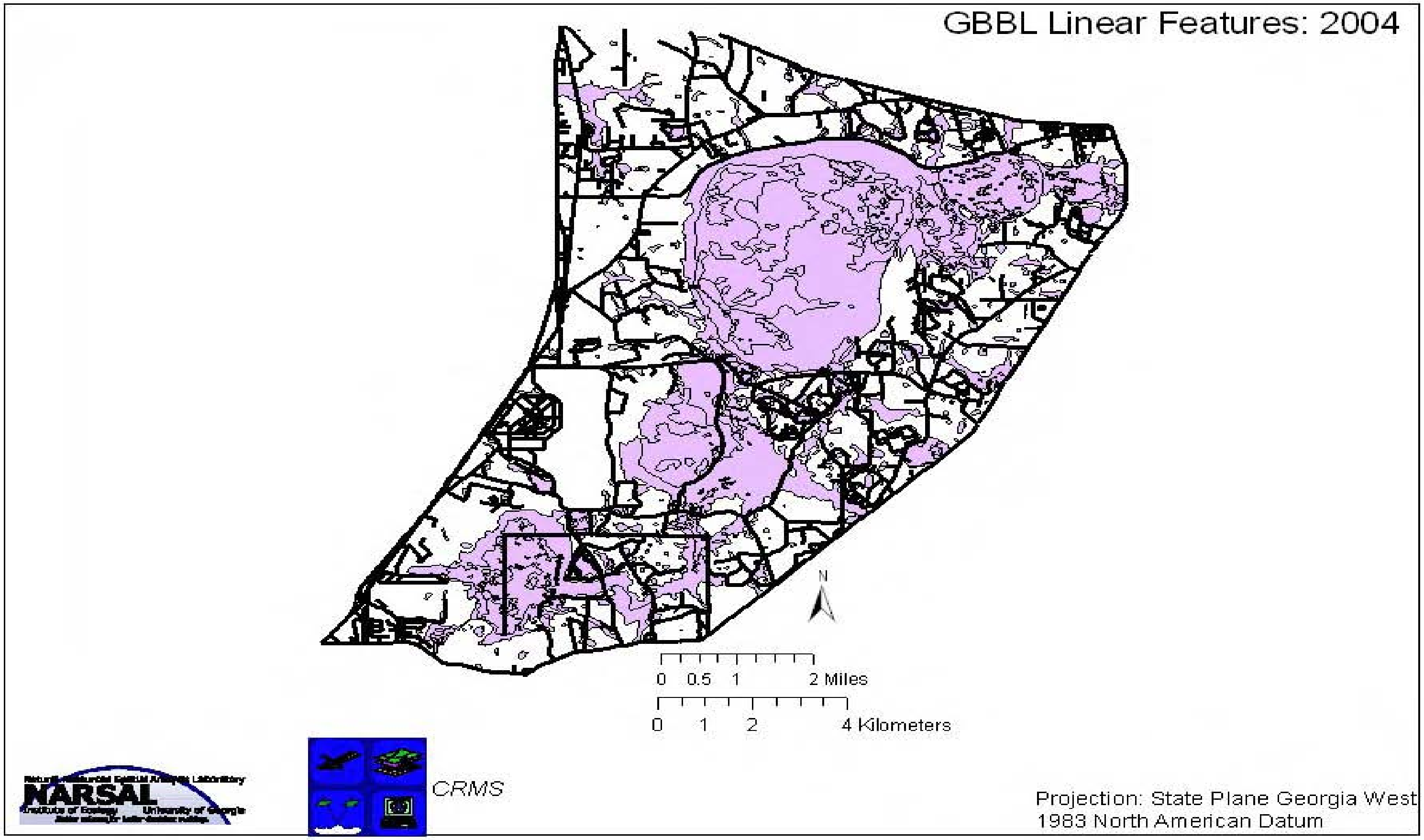

Figure 3f. Linear features (roads and hydrological modifications) within Grand Bay-Banks Lake (GBBL) ecosystem in 2004. Polygons represent all wetland classes within GBBL study area at this date.

Figure 4. Example of recent urbanization within the Grand Bay-Banks Lake (GBBL) ecosystem. Highway 122 and the forested rim of Oldfield Bay can be seen on the far right side of the photograph. Photograph was taken on February 17, 2006.

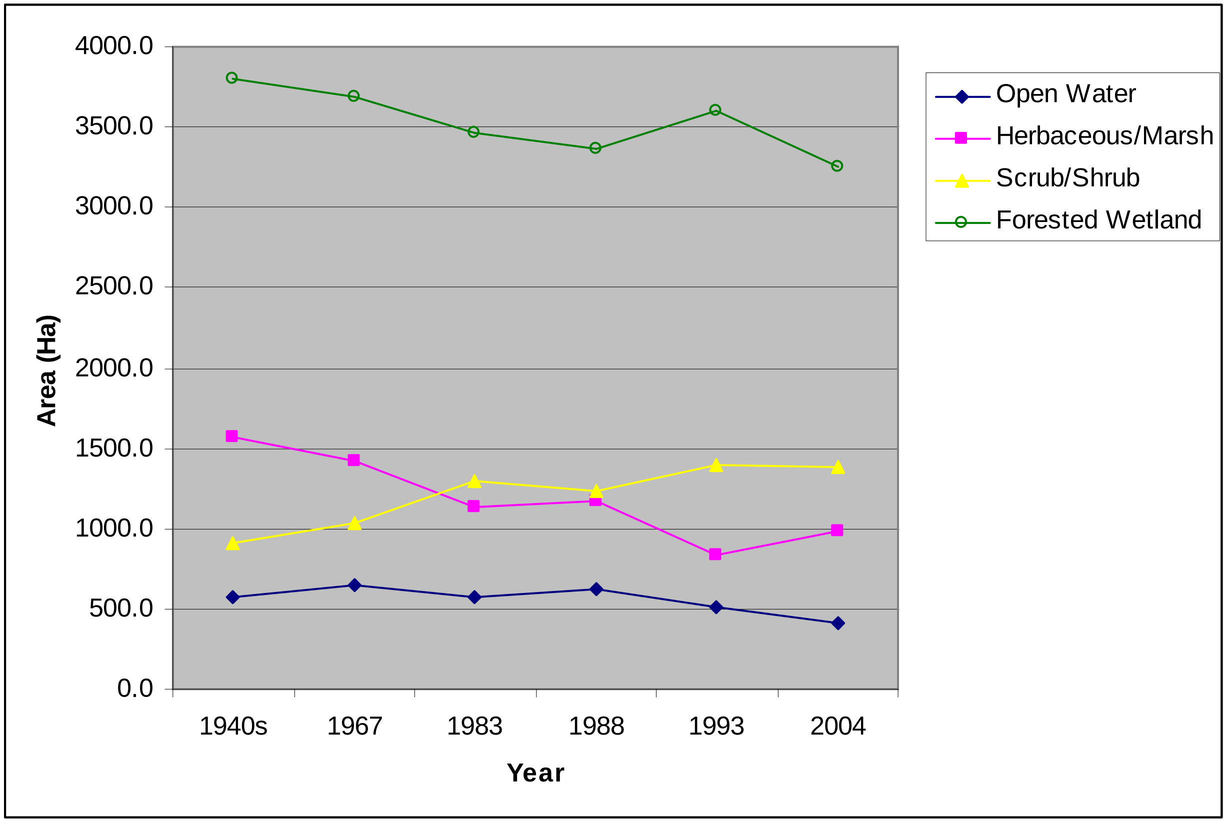

Figure 5. Total area (hectares) of selected wetland classes within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s to 2004.

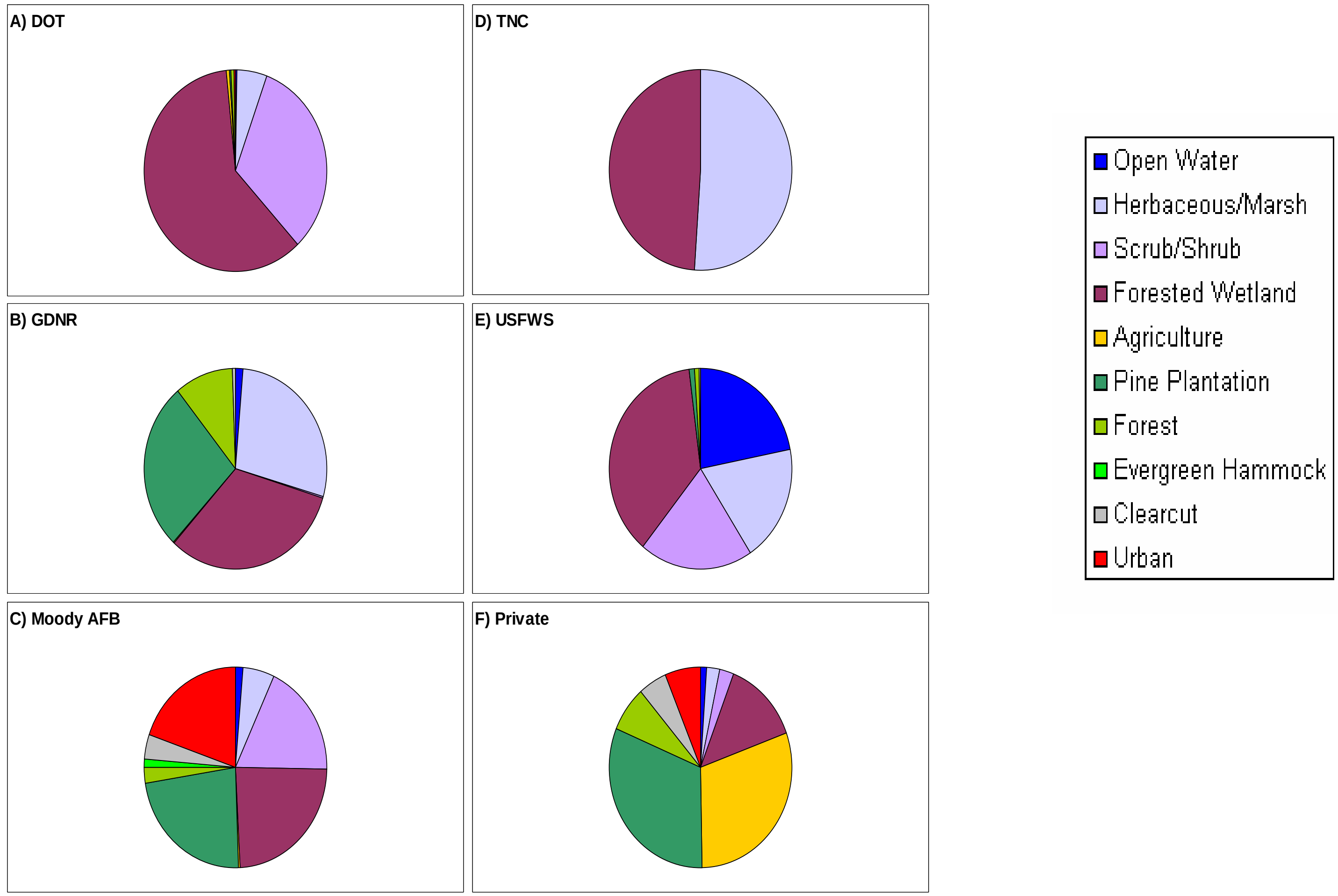

Figure 6(a-f). Composition of 2004 land cover within Grand Bay-Banks Lake (GBBL) study area on land owned by a) Department of Transportation (DOT), b) Georgia Department of Natural Resources (GDNR), c) Moody Air Force Base (Moody AFB), d) Nature Conservancy (TNC), e) United States Fish and Wildlife Service (USFWS), and f) private.

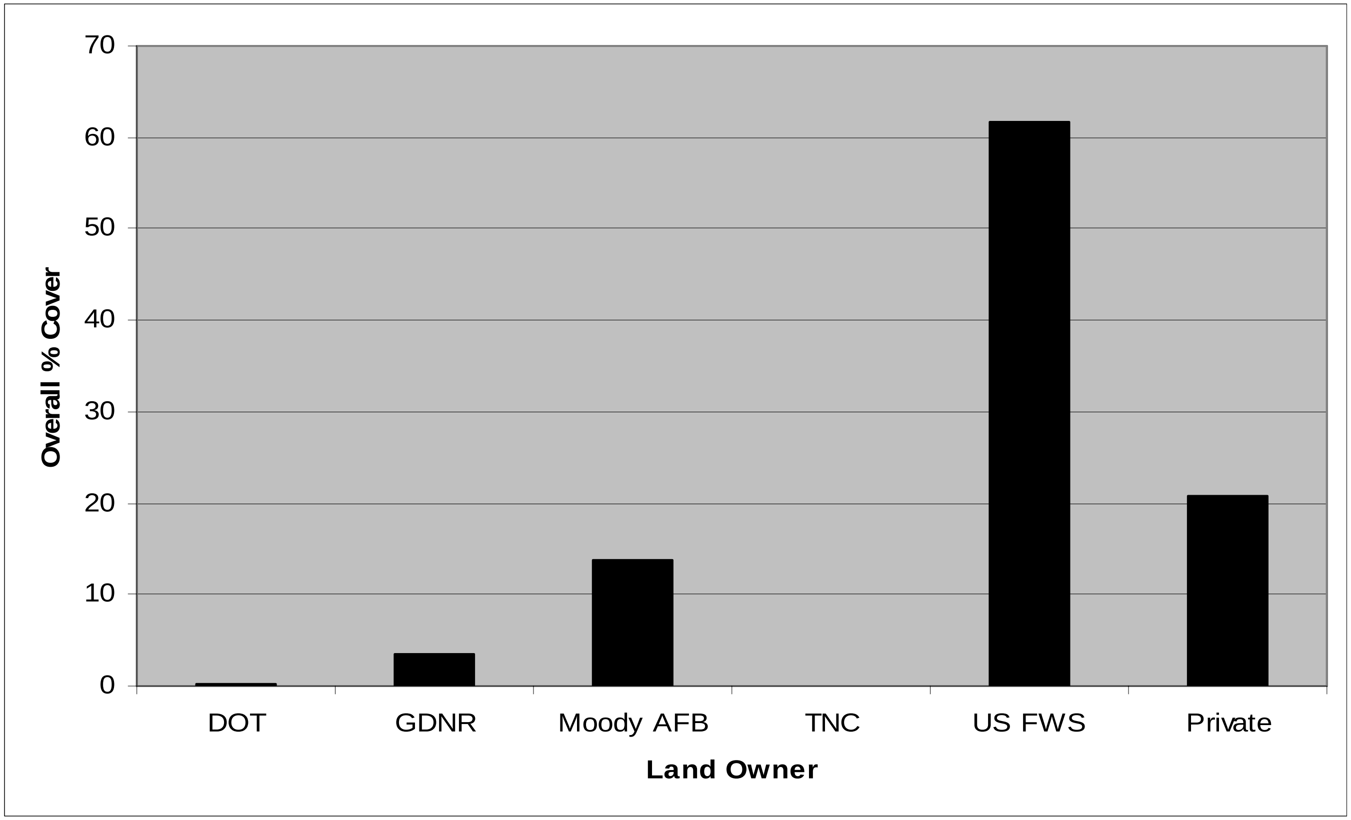

Figure 7a. Distribution of open water (% cover) within Grand Bay-Banks Lake (GBBL) ecosystem by land owner in 2004.

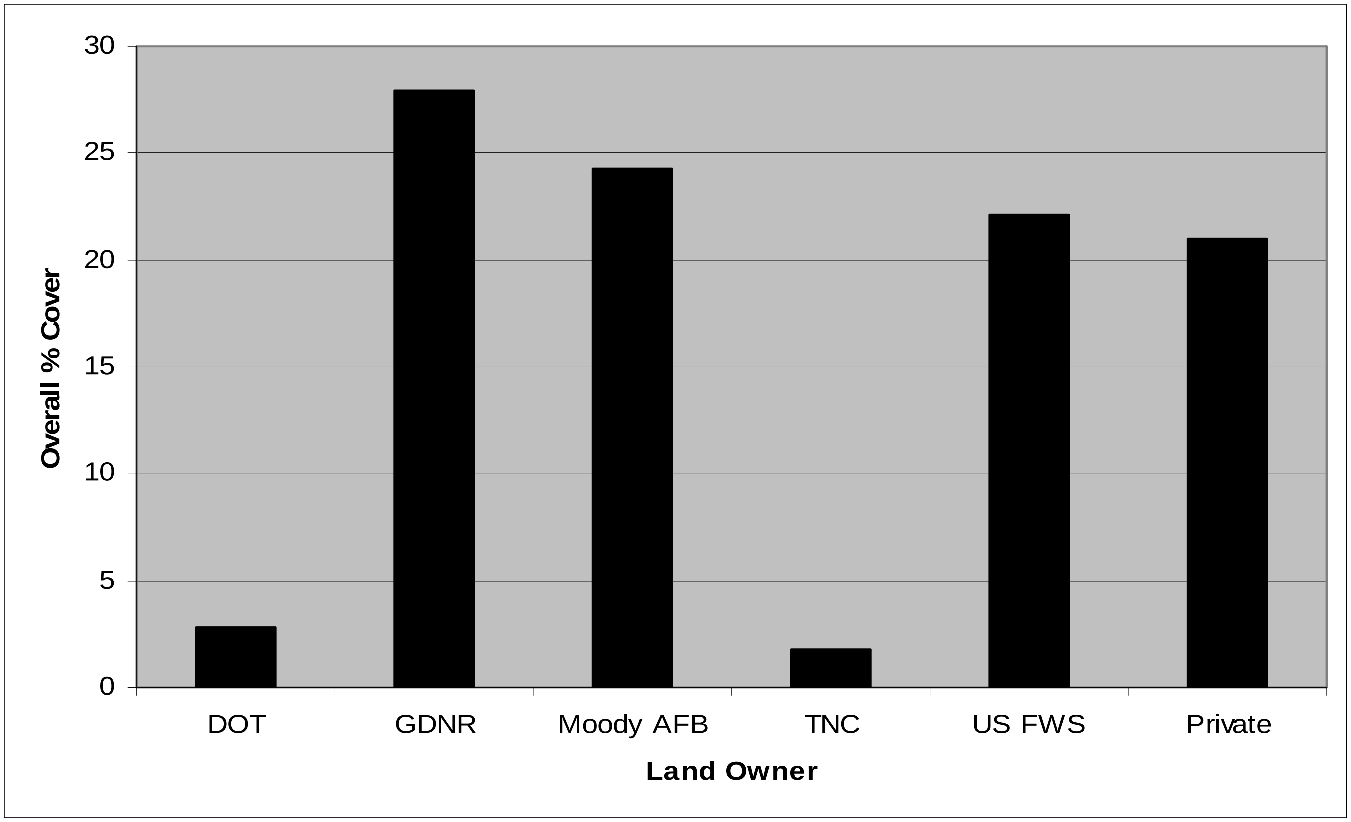

Figure 7b. Distribution of herbaceous/marsh (% cover) within Grand Bay-Banks Lake (GBBL) ecosystem by land owner in 2004.

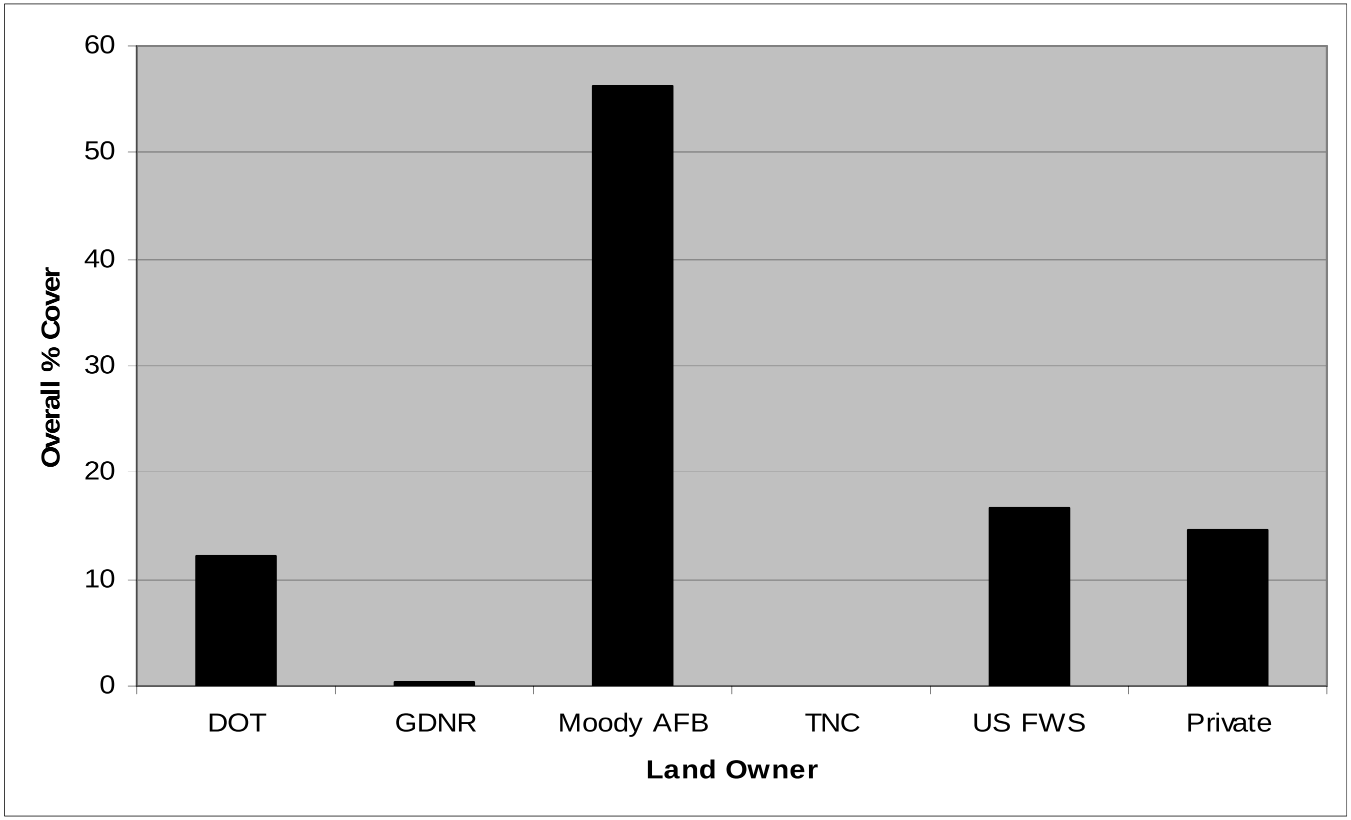

Figure 7c. Distribution of scrub/shrub (% cover) within Grand Bay-Banks Lake (GBBL) ecosystem by land owner in 2004.

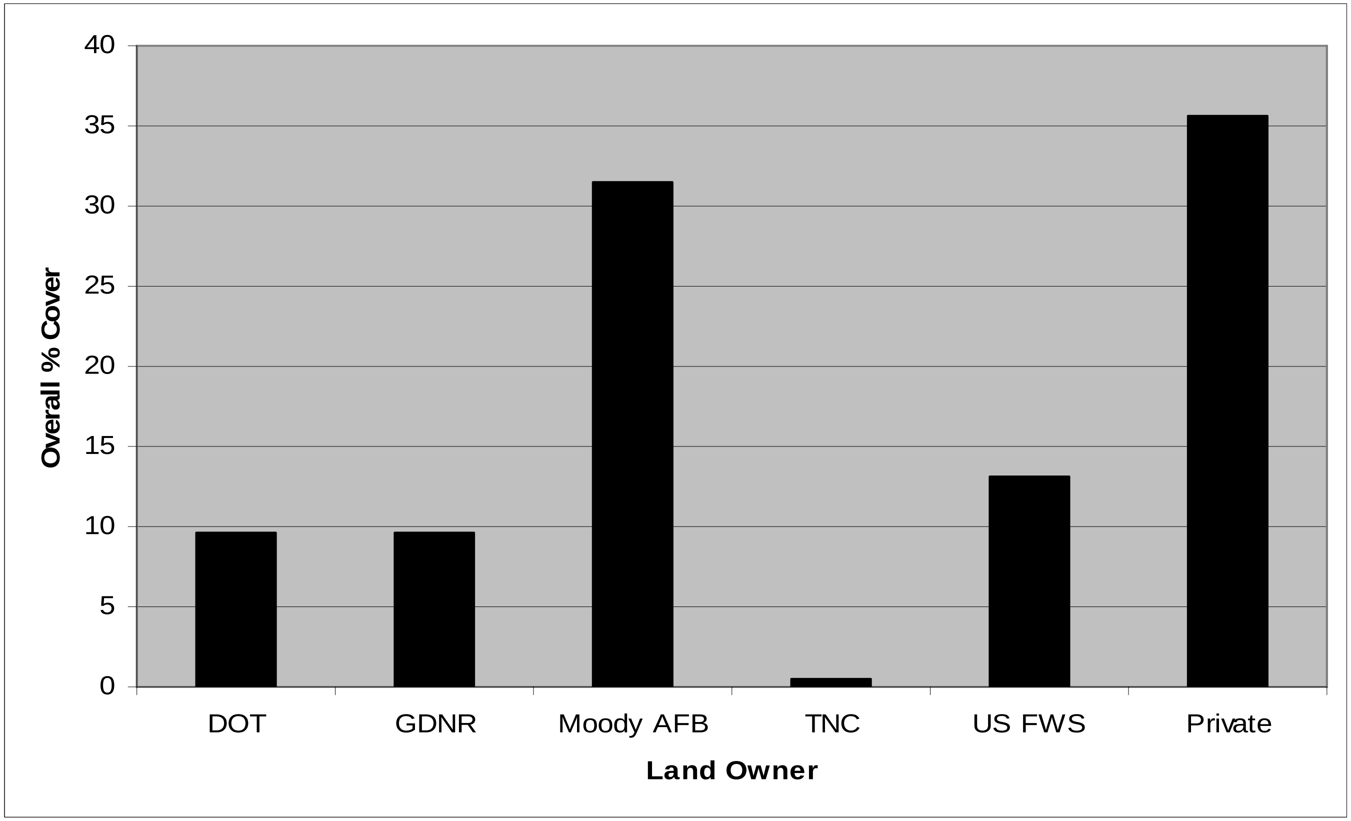

Figure 7d. Distribution of forested wetland (% cover) within Grand Bay-Banks Lake (GBBL) ecosystem by land owner in 2004.

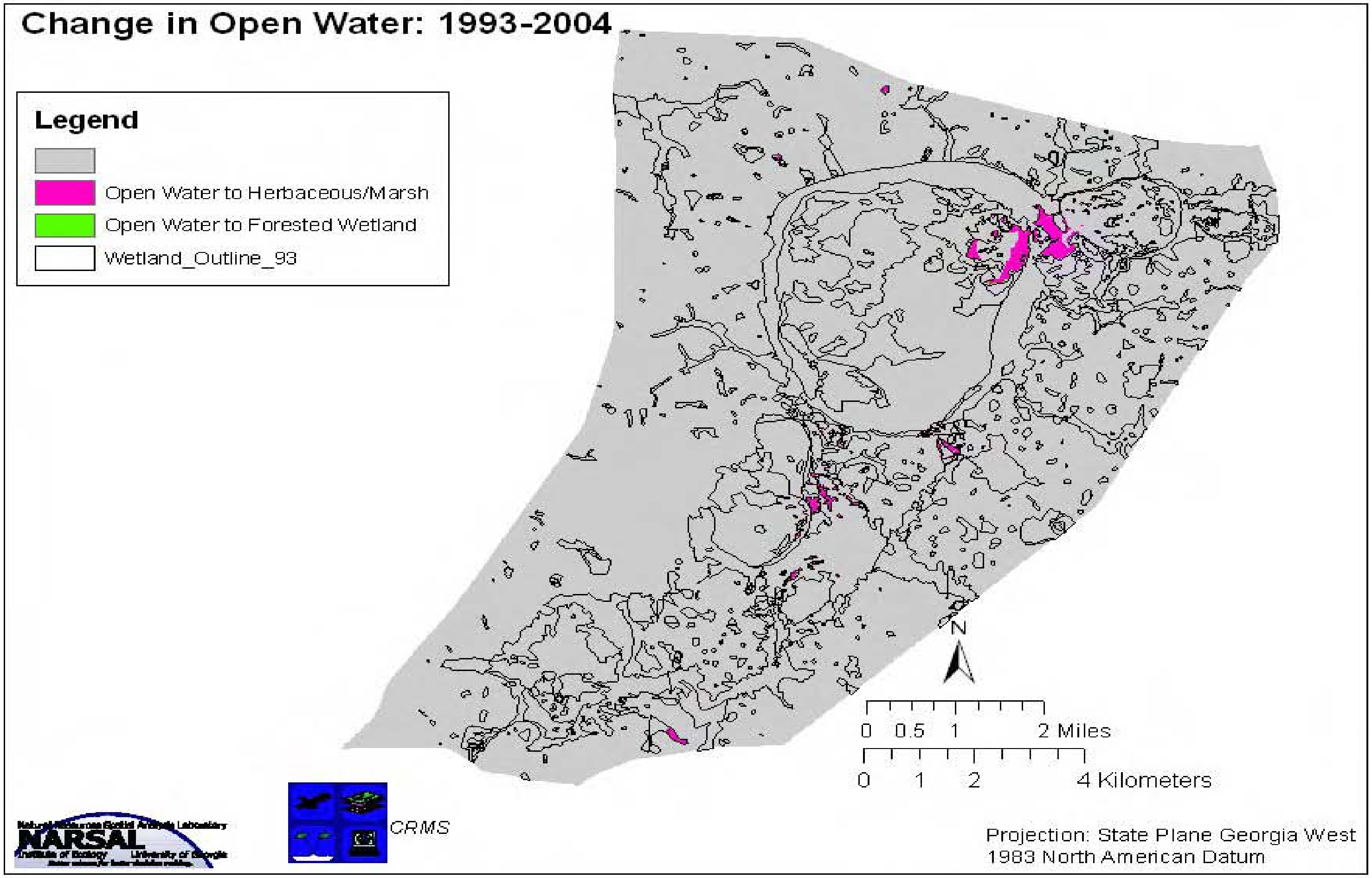

Figure 8a. Change analysis of open water within Grand Bay-Banks Lake (GBBL) ecosystem from 1993-2004.

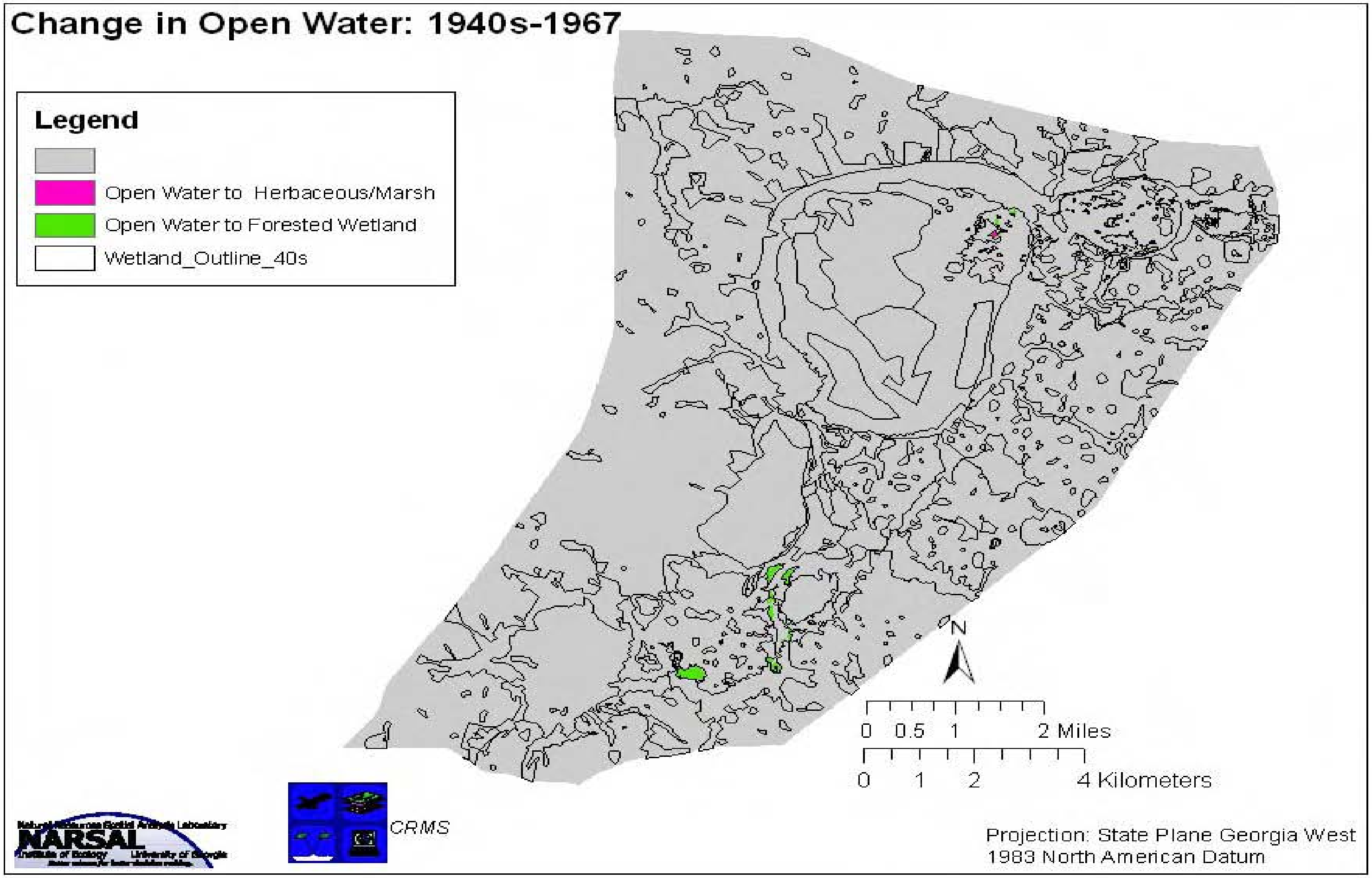

Figure 8b. Change analysis of open water within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s-1967.

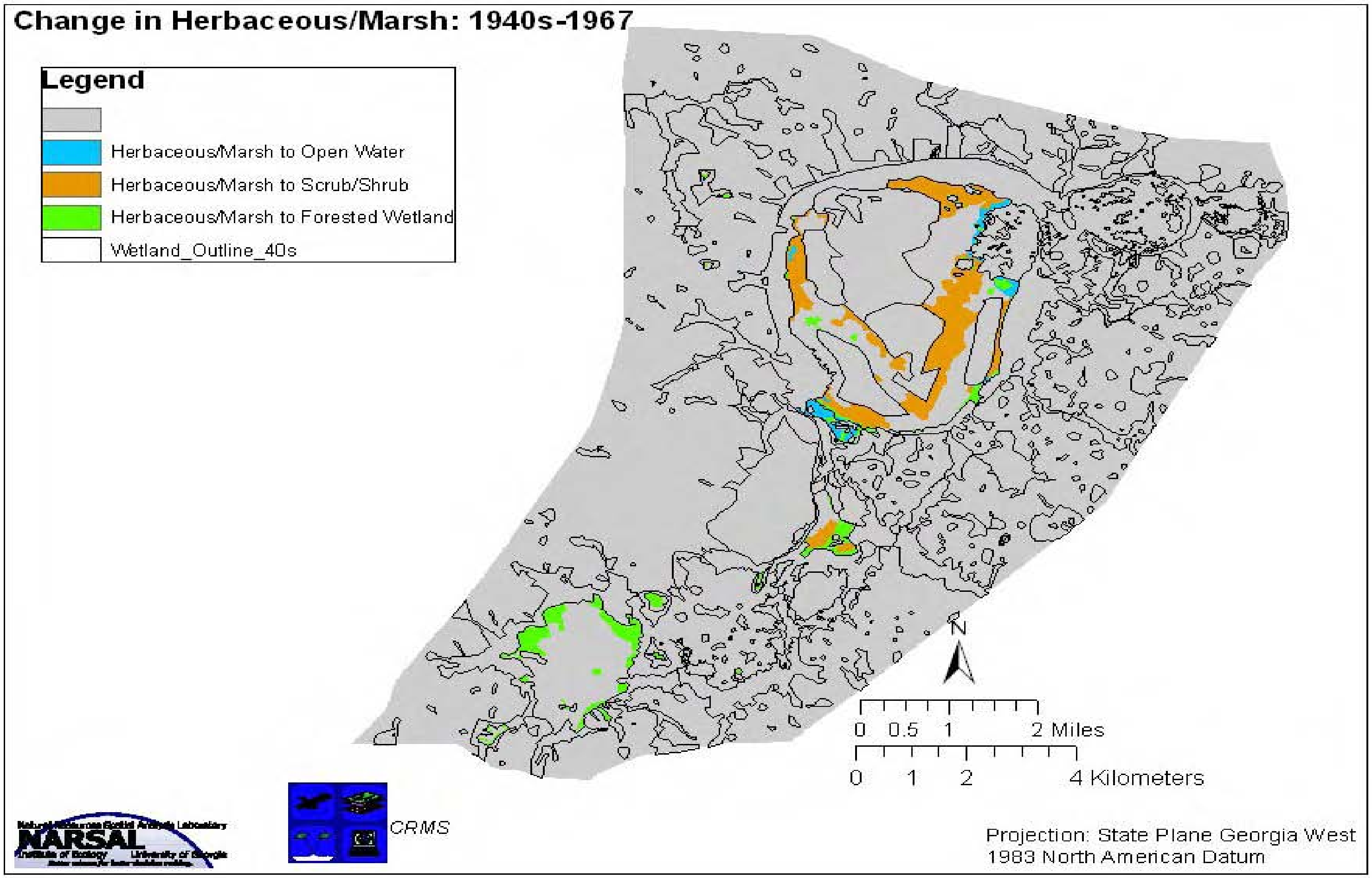

Figure 9a. Change analysis of herbaceous/marsh within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s-1967.

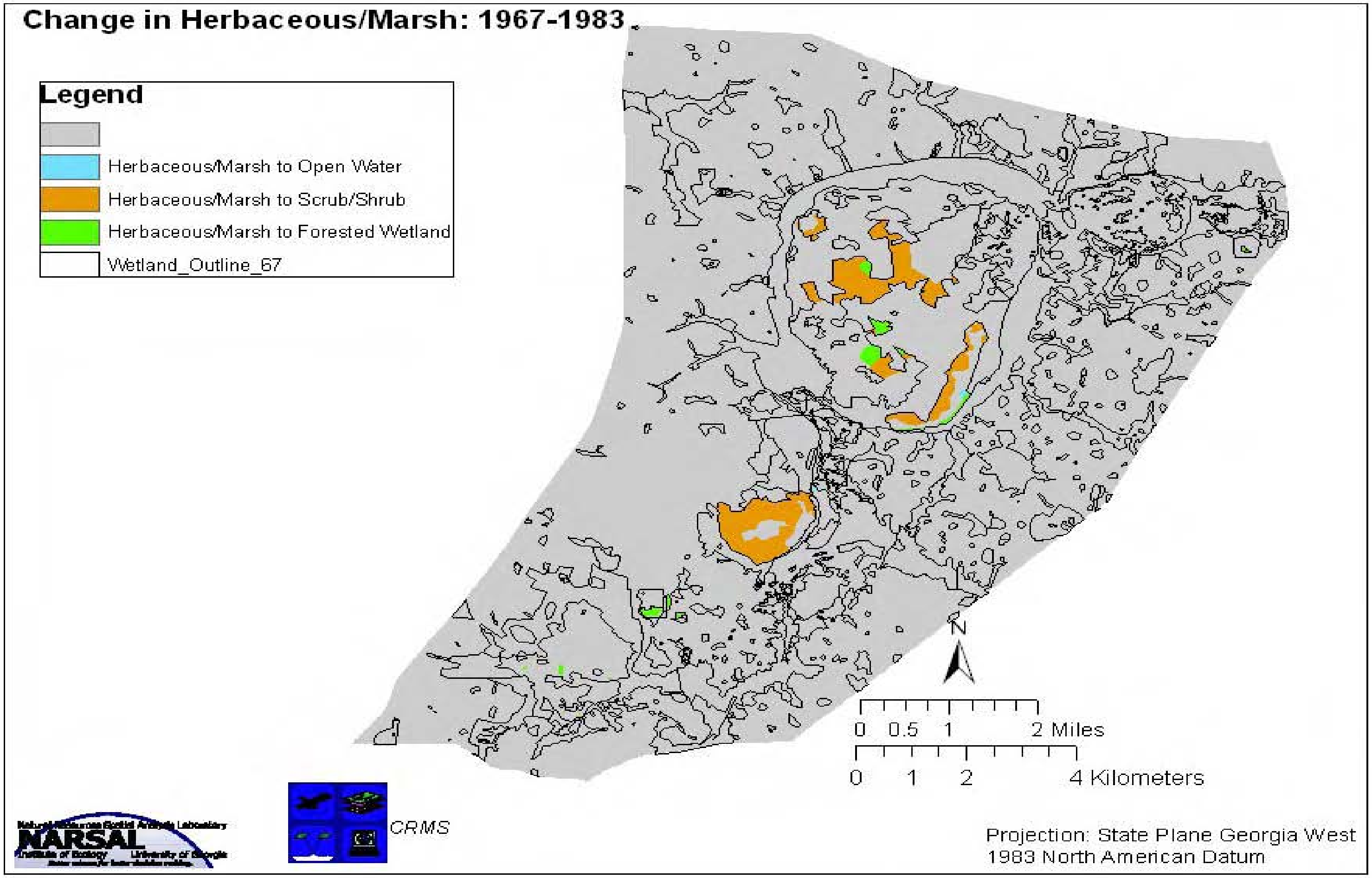

Figure 9b. Change analysis of herbaceous/marsh within Grand Bay-Banks Lake (GBBL) ecosystem from 1967-1983.

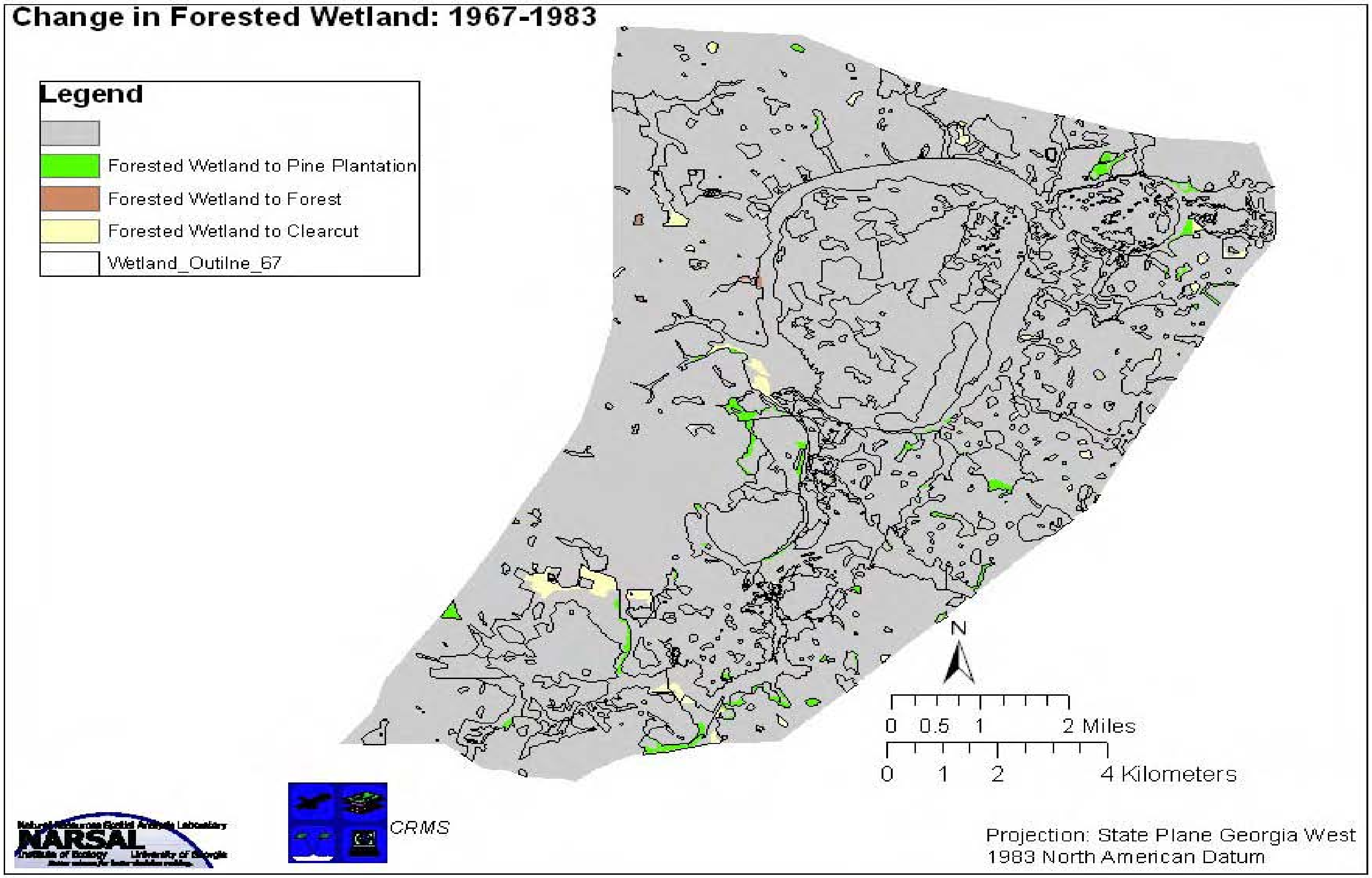

Figure 10a. Change analysis of forested wetland within Grand Bay-Banks Lake (GBBL) ecosystem from 1967-1983.

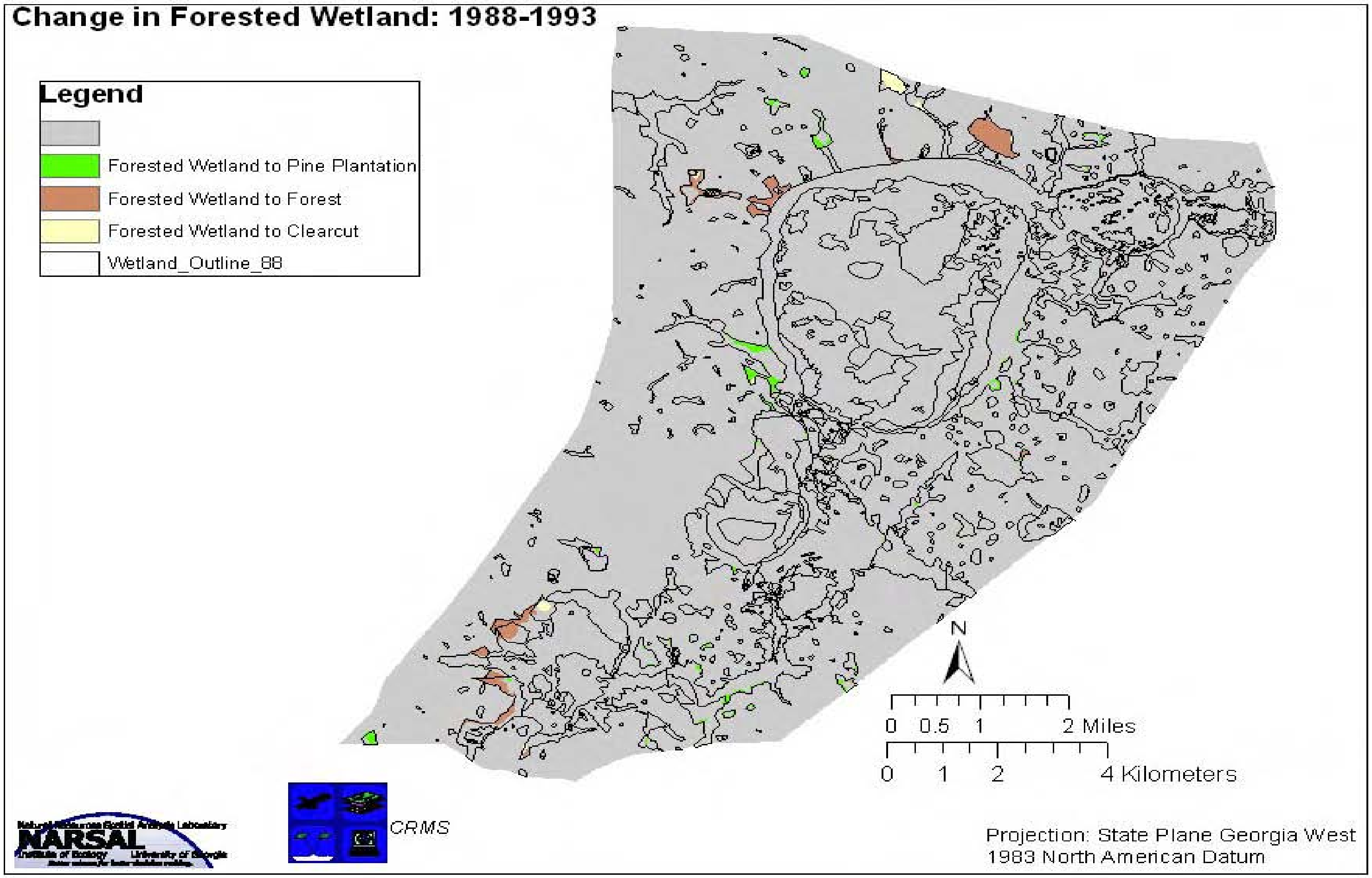

Figure 10b. Change analysis of forested wetland within Grand Bay-Banks Lake (GBBL) ecosystem from 1988-1993.

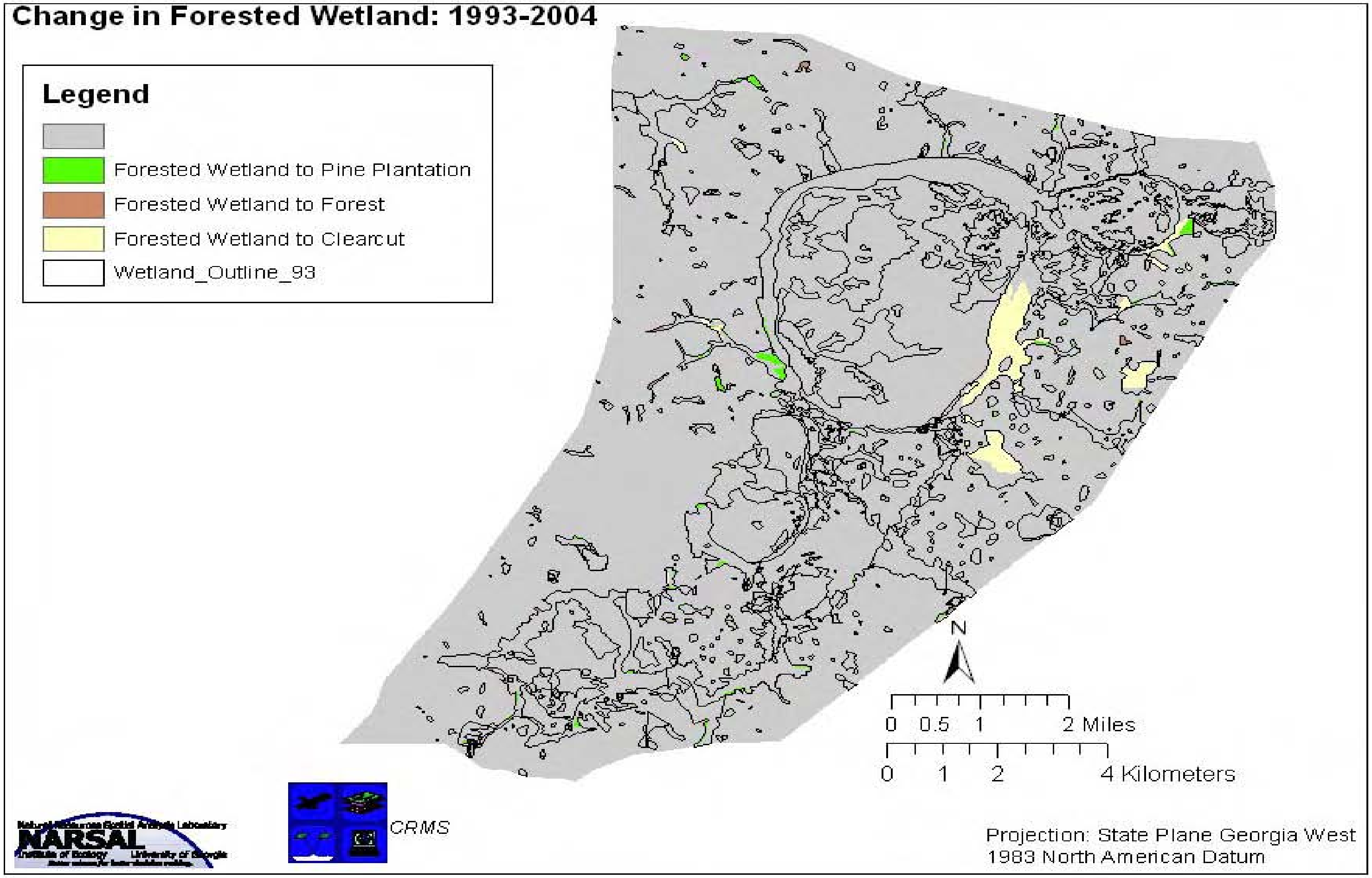

Figure 10c. Change analysis of forested wetland within Grand Bay-Banks Lake (GBBL) ecosystem from 1993-2004.

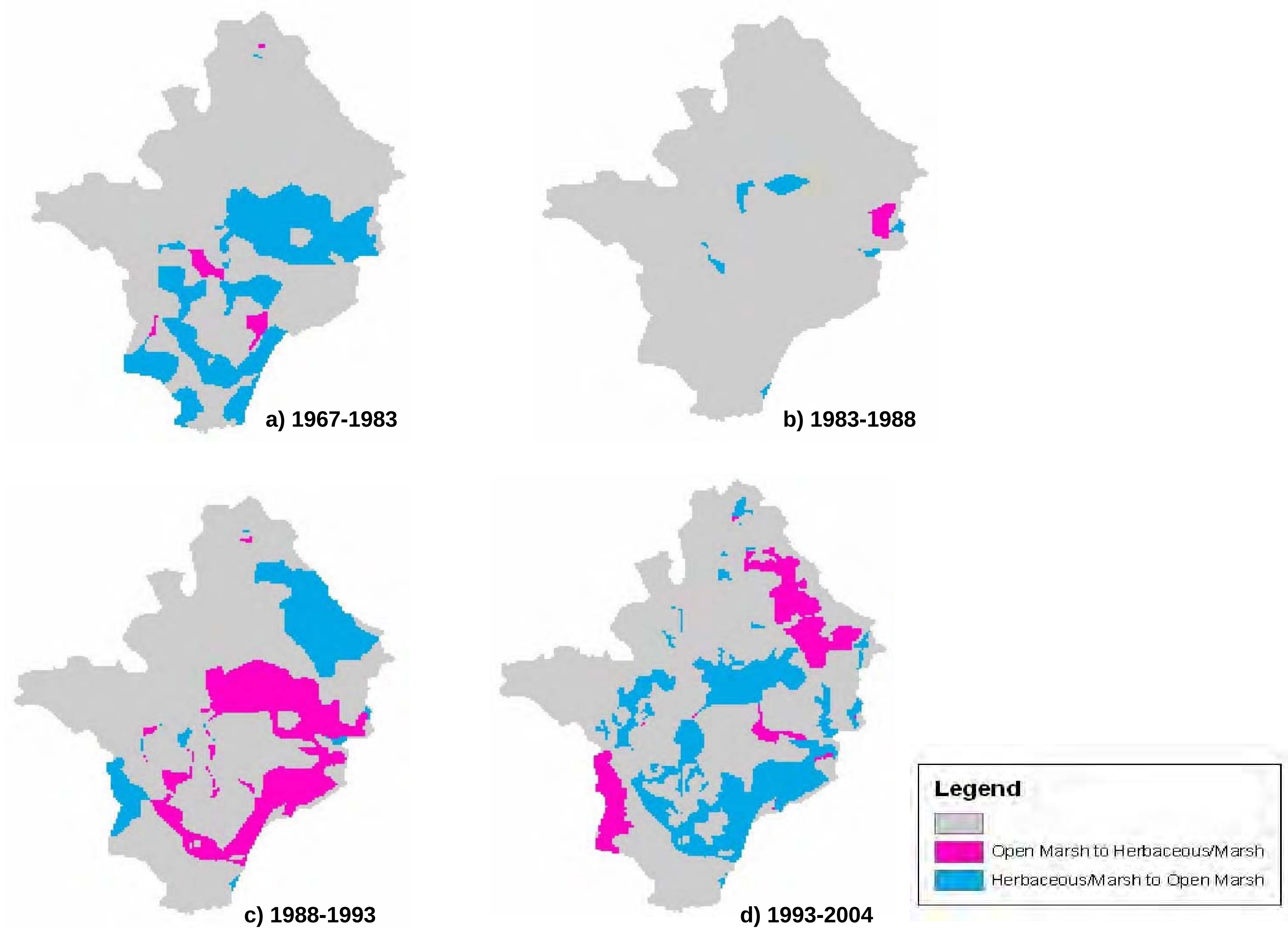

Figure 11(a-d). Change in open marsh and herbaceous/marsh within Grand Bay from a)1967-1983, b)1983-1988, c)1988-1993, and d)1993-2004.

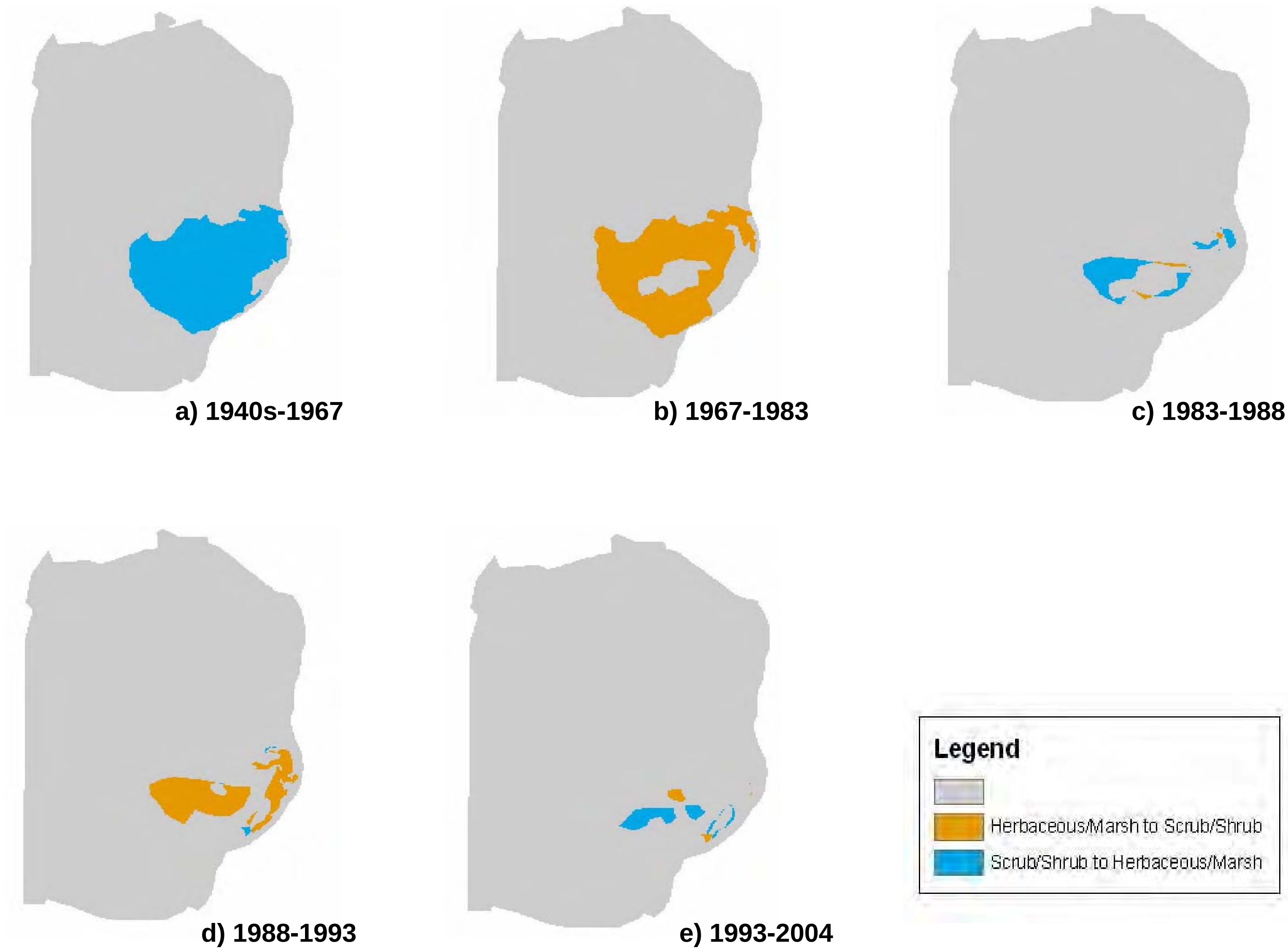

Figure 12(a-e). Change in herbaceous/marsh and scrub/shrub within Moody Bay from a) 1940s-1967, b) 1967-1983, c) 1983-1988, d) 1988-1993, and e) 1993-2004

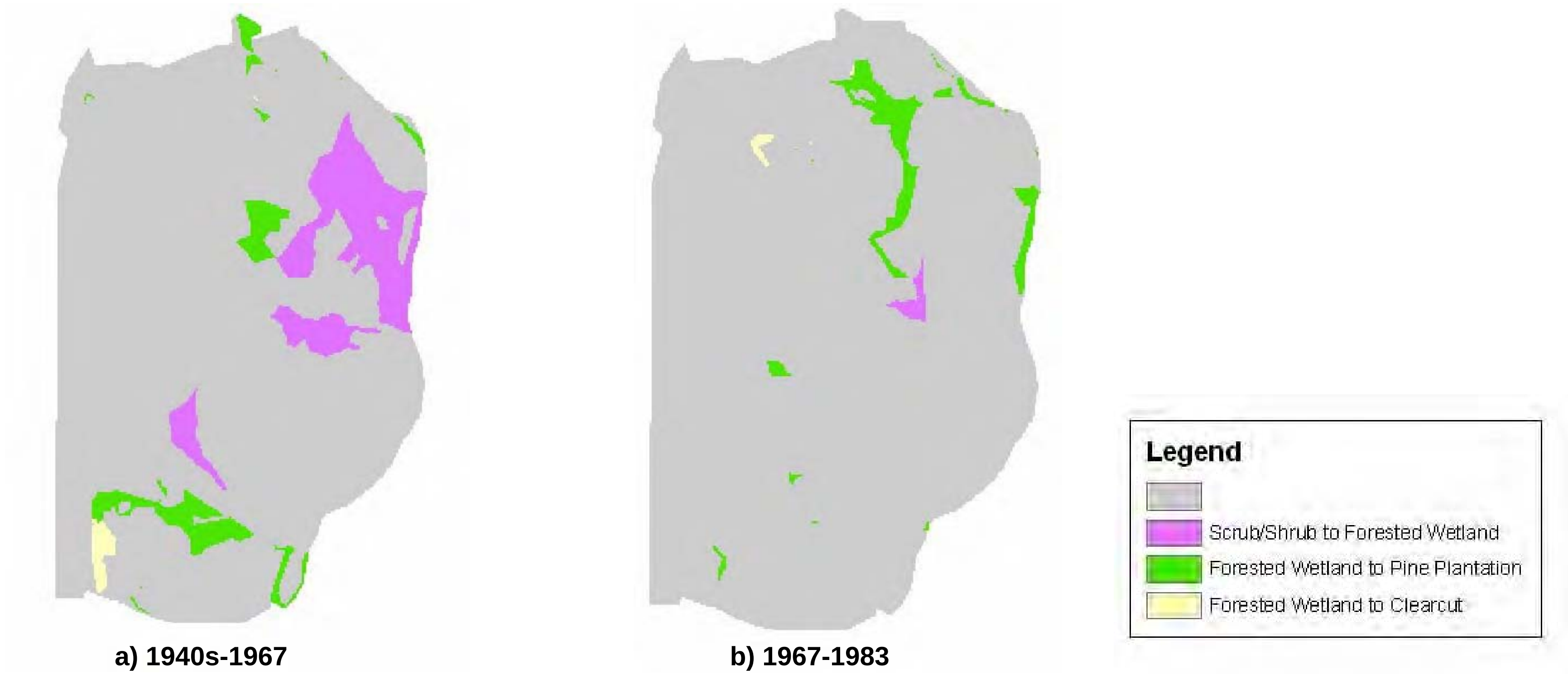

Figure 13. Change in scrub/shrub and forested wetland within Moody Bay from a) 1940s-1967 and b) 1967-1983.

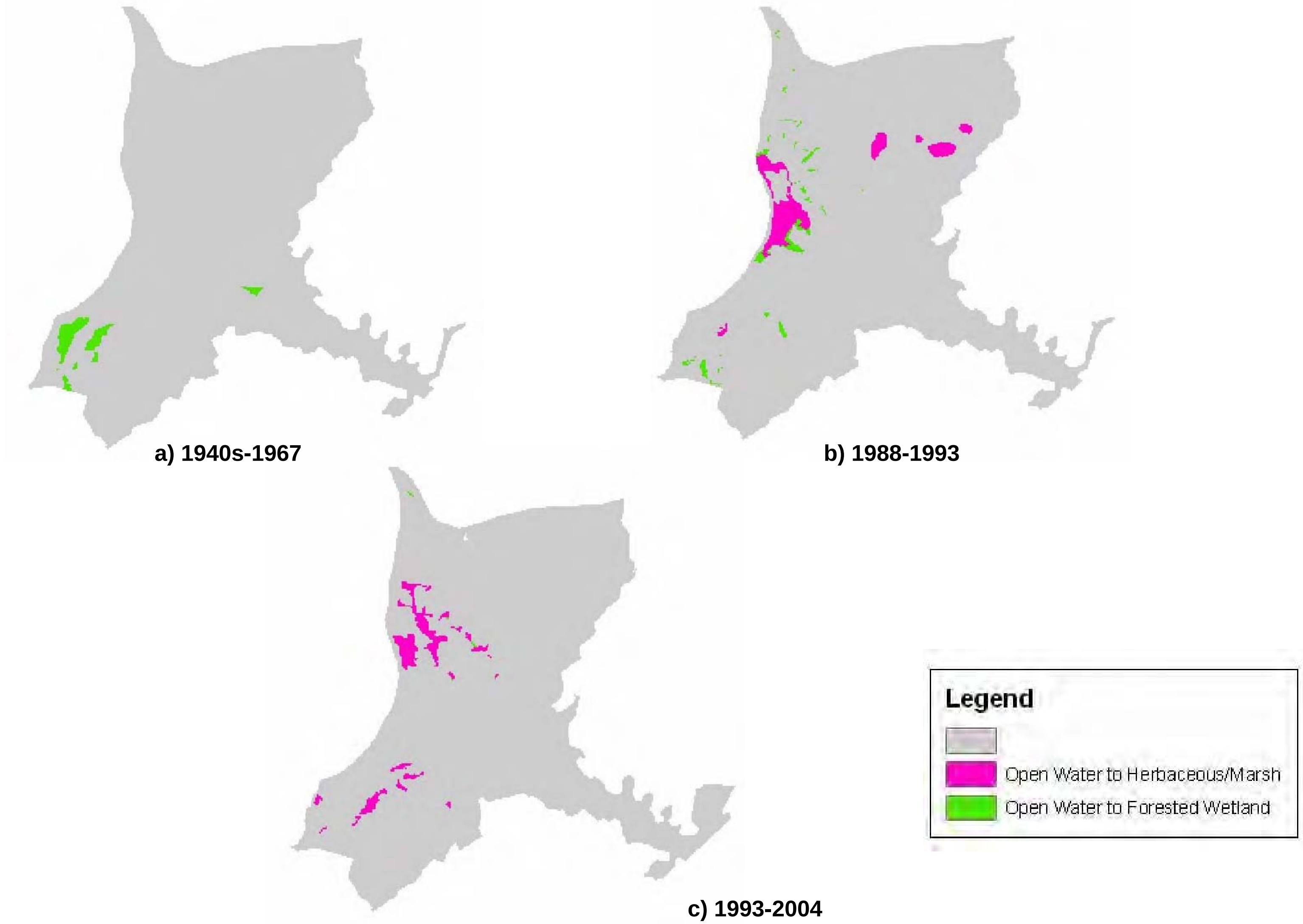

Figure 14(a-c). Change in open water within Rat Bay and surrounding areas from a) 1940s-1967, b) 1988-1993 and c) 1993-2004.

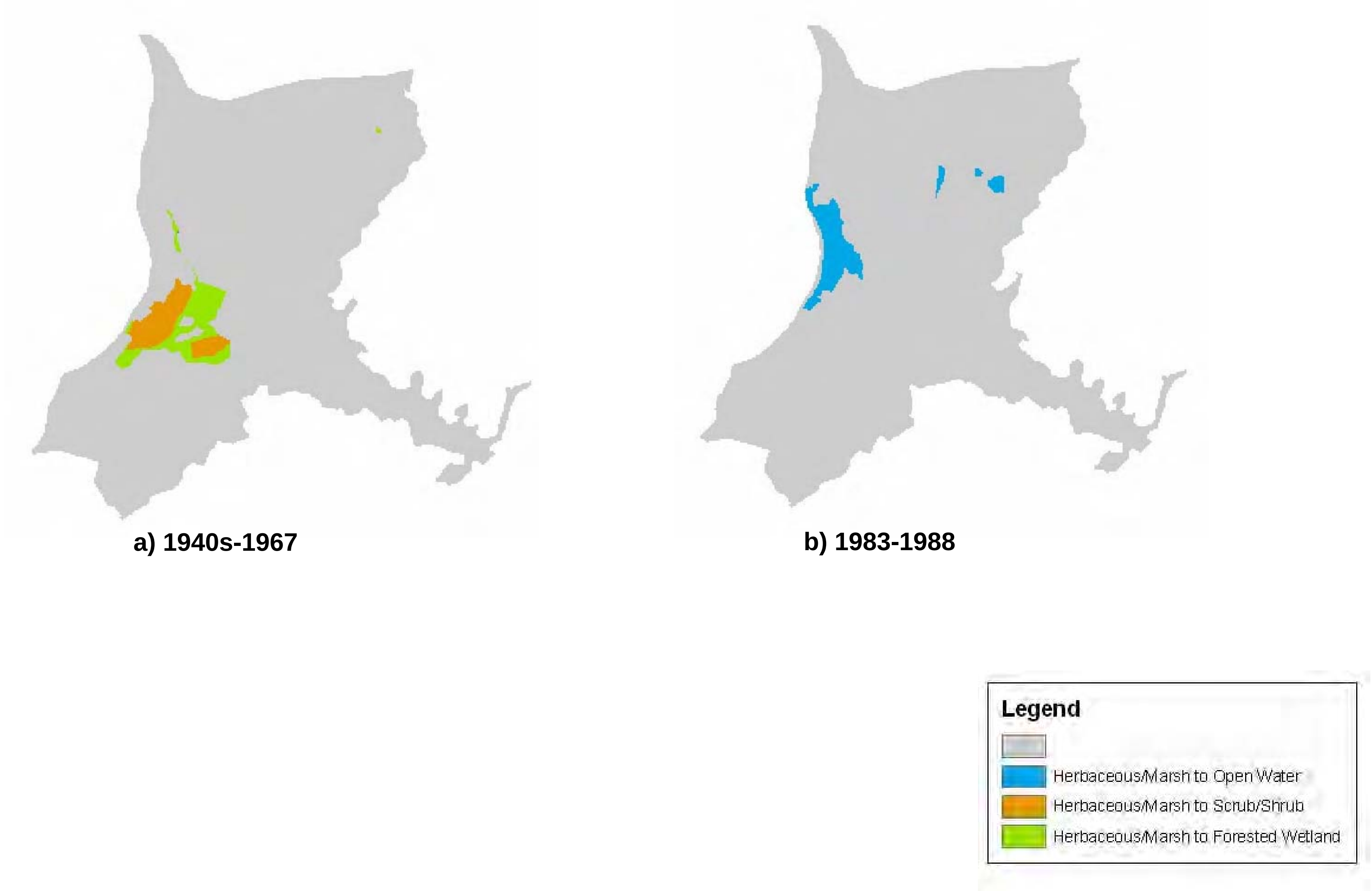

Figure 15(a-b). Change in herbaceous/marsh within Rat Bay and surrounding area from a) 1940s-1967 and b) 1983-1988.

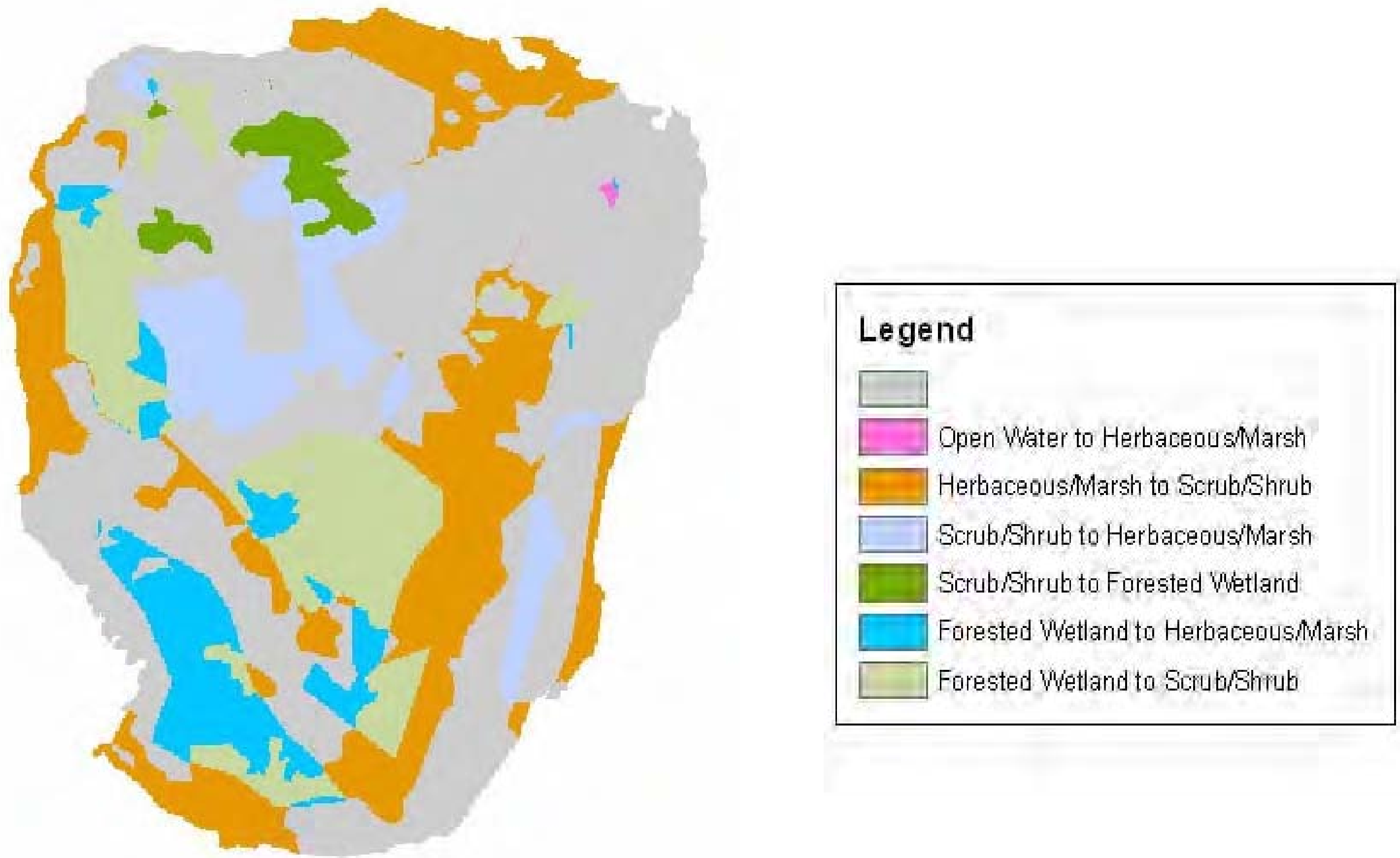

Figure 16. Various changes within Oldfield Bay from 1940s-1967.

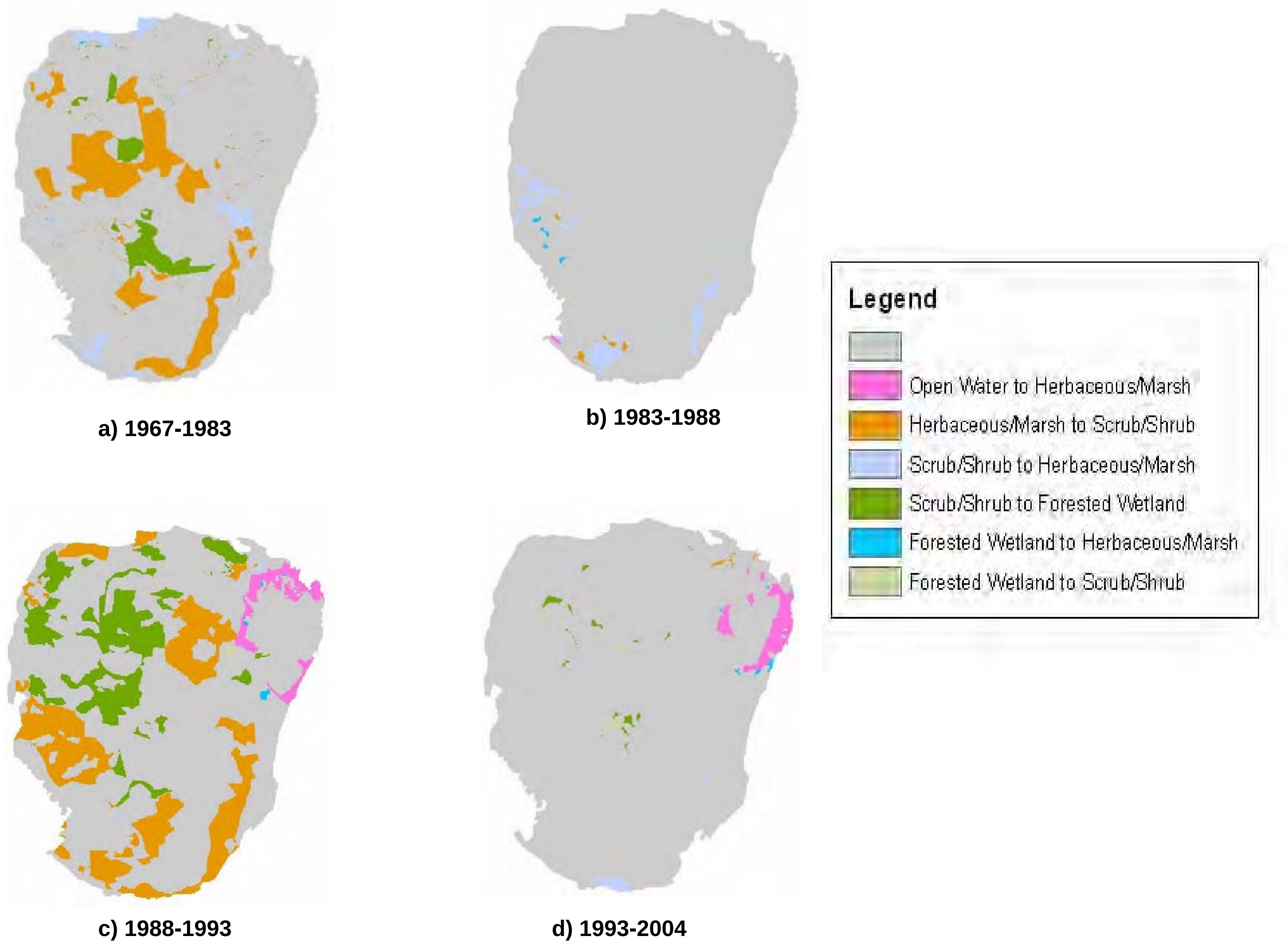

Figure 17(a-d). Various changes within Oldfield Bay from a) 1967-1983, b) 1983-1988, c) 1988-1993, and d) 1993-2004.

Figure 18. Example of herbaceous/marsh in the southwestern section of Oldfield Bay. Area was accessed from the trail adjacent to the western edge of Shiner's Pond. Photograph was taken on February 17, 2006.

Table 1. Summary of aerial photography used to map land cover of Grand Bay-Banks Lake (GBBL) ecosystem.

Date	Photo Scale	Source	Type
1940s	1:20000	Agricultural Stabilization and Conservation Service (ACSC)	Black and white
1967	1:20000	Agricultural Stabilization and Conservation Service (ACSC)	Black and white
1983	1:58000	USGS National High Altitude Aerial Photography (NHAP) program	Color infrared
1988	1:40000	USGS National Aerial Photography Program (NAPP)	Color infrared
1993	1:40000	Digital ortho quater quads (DOQQs) based on USGS National Aerial Photography Program (NAPP)	Black and white
2004	1:4800 – 1:26400 1:40000	Moody Air Force Base 1999 DOQQs	True color Color infrared

Table 2. Land cover classification used for mapping of Grand Bay-Banks Lake (GBBL) ecosystem.

Land Cover Classes	Modifiers	Additional Information
Agriculture	---	
Bottomland Hardwood	Riparian	
Clearcut	---	
Clearcut Wetland	---	Wetland status based on earlier photographs and other evidence (e.g. dark stained soils)
Cypress-Gum Swamp	Mixed, Riparian	
Deciduous Forest	---	
Evergreen Forested Wetland	---	
Evergreen Hammock	---	Dudley’s Hammock, Moody Air Force Base
Herbaceous/Marsh	---	Wet areas with aquatic and/or emergent vegetation
Longleaf Pine	---	
Mixed Forest	---	
Open Marsh	---	Designation used only within Grand Bay which doesn’t have true open water, but vegetation appears to be less dense than typical herbaceous/marsh
Open Water	---	Includes agricultural ponds
Pine Plantation	---	Potentially includes natural stands of pine
Scrub/Shrub	---	When possible, “evergreen” or “deciduous” is included in Notes field of geodatabase
Urban	---	
Woodland	---	Forested areas with open canopy; look successional; primarily in earlier photos; 1940s land cover might include some Longleaf pine

Table 3a. Summary of Grand Bay-Banks Lake (GBBL) ecosystem land cover from 1940s to 2004. Several classes that were mapped were merged for data analysis (see Methods and table footnote).

	1940s		1967		1983		1988		1993		2004		
Land Cover Class	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Net Change (1940s-2004)**
Open Water	571	3.7	650	4.2	573	3.7	625	4.1	514	3.3	406	2.6	-165 ha (-1.1 %)
Herbaceous/Marsh*	1566	10.2	1416	9.2	1137	7.4	1174	7.6	837	5.4	984	6.4	-582 ha (-3.8 %)
Scrub/Shrub	913	5.9	1029	6.7	1295	8.4	1234	8.0	1397	9.1	1388	9.0	475 ha (3.1 %)
Forested Wetland*	3804	24.7	3693	24.0	3464	22.5	3367	21.8	3602	23.4	3256	21.1	-548 ha (-3.6 %)
Agriculture	3030	19.7	3042	19.7	3259	21.1	3279	21.3	2806	18.2	2566	16.6	-464 ha (-3.0 %)
Woodland	2912	18.9	404	2.6	69	0.4	65	0.4	0	0.0	0	0.0	-2912 ha (-18.9 %)
Pine Plantation*	976	6.3	3515	22.8	3334	21.6	3345	21.7	3570	23.1	3938	25.5	2962 ha (19.2 %)
Forest*	45	0.3	384	2.5	318	2.1	373	2.4	811	5.3	846	5.5	801 ha (5.2 %)
Evergreen Hammock	61	0.4	64	0.4	64	0.4	64	0.4	62	0.4	58	0.4	-3 ha (0.0 %)
Clearcut*	859	5.6	367	2.4	1021	6.6	1005	6.5	690	4.5	598	3.9	-261 ha (-1.7 %)
Urban	679	4.4	853	5.5	886	5.7	885	5.7	1132	7.3	1381	9.0	702 ha (4.5 %)

* Herbaceous/Marsh = Herbaceous/Marsh and Open Marsh
Forested Wetland = all Bottomland Hardwood, Cypress-Gum Swamp, and Evergreen Forested Wetland classes
Pine Plantation = Pine Plantation and Longleaf Pine
Forest = Deciduous Forest and Mixed Forest
Clearcut = Clearcut and Clearcut Wetland

Table 3b. Summary of Grand Bay-Banks Lake (GBBL) ecosystem land cover (acres) from 1940s to 2004. Several classes that were mapped were merged for data analysis (see Methods and table footnote).

Land Cover Class	1940s Area (Acres)	1967 Area (Acres)	1983 Area (Acres)	1988 Area (Acres)	1993 Area (Acres)	2004 Area (Acres)	Net Change (1940s-2004)
Open Water	1409	1604	1415	1543	1269	1003	-406
Herbaceous/Marsh*	3867	3496	2808	2898	2066	2429	-1438
Scrub/Shrub	2255	2540	3198	3047	3450	3428	1173
Forested Wetland*	9393	9119	8552	8313	8894	8040	-1353
Agriculture	7482	7511	8046	8095	6928	6336	-1146
Woodland	7190	998	162	161	0	0	-7190
Pine Plantation*	2409	8678	8233	8260	8814	9724	7315
Forest*	112	947	786	921	2002	2089	1977
Evergreen Hammock	152	159	158	159	152	144	-8
Clearcut*	2121	907	2520	2483	1703	1477	-644
Urban	1676	2107	2187	2185	2796	3409	1733

* Herbaceous/Marsh = Herbaceous/Marsh and Open Marsh
Forested Wetland = all Bottomland Hardwood, Cypress-Gum Swamp, and Evergreen Forested Wetland classes
Pine Plantation = Pine Plantation and Longleaf Pine
Forest = Deciduous Forest and Mixed Forest
Clearcut = Clearcut and Clearcut Wetland

Table 4. Total length of linear features (roads and hydrological modifications) present within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s – 2004.

Year	**Total Linear Features (Miles)**
1941/1943	160
1967	190
1983	204
1988	218
1993	245
2004	254

Table 5a. 2004 land cover values for Department of Transportation (DOT) property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on DOT property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	Area (ha)	% by Owner	Overall %
Open Water	1	0.1	0.2
Herbaceous/Marsh	28	5.4	2.8
Scrub/Shrub	170	32.7	12.2
Forested Wetland	313	60.2	9.6
Agriculture	3	0.5	0.1
Pine Plantation	1	0.2	0.0
Forest	3	0.5	0.3
Urban	2	0.4	0.0
TOTAL	520	--	3.4

Table 5b. 2004 land cover values for Georgia Department of Natural Resources (GDNR) property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on GDNR property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	Area (ha)	% by Owner	Overall %
Open Water	14	1.5	3.5
Herbaceous/Marsh	275	28.0	28.0
Scrub/Shrub	4	0.4	0.3
Forested Wetland	313	31.8	9.6
Agriculture	4	0.4	0.1
Pine Plantation	267	27.2	6.8
Forest	101	10.2	11.9
Clearcut	5	0.5	0.8
Urban	1	0.1	0.8
TOTAL	984	--	6.4

Table 5c. 2004 land cover values for Moody Air Force Base (Moody AFB) property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on Moody AFB property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	Area (ha)	% by Owner	Overall %
Open Water	56	1.3	13.8
Herbaceous/Marsh	239	5.6	24.3
Scrub/Shrub	781	18.3	56.2
Forested Wetland	1024	24.0	31.5
Agriculture	3	0.1	0.1
Pine Plantation	984	23.1	25.0
Forest	109	2.5	12.9
Evergreen Hammock	58	1.4	100.0
Clearcut	169	4.0	28.3
Urban	840	19.7	60.8
TOTAL	4263	--	27.6

Table 5d. 2004 land cover values for The Nature Conservancy (TNC) property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on TNC property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	Area (ha)	% by Owner	Overall %
Herbaceous/Marsh	18	51.0	1.8
Forested Wetland	17	48.8	0.5
Pine Plantation	0	0.1	0.0
TOTAL	35	—	0.2

Table 5e. 2004 land cover values for the United States Fish and Wildlife Service (USFWS) property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on USFWS property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	**Area (ha)**	**% by Owner**	**Overall %**
Open Water	251	21.8	61.8
Herbaceous/Marsh	218	18.9	22.1
Scrub/Shrub	232	20.1	16.7
Forested Wetland	429	37.3	13.2
Agriculture	0	0.0	0.0
Pine Plantation	8	0.7	0.2
Forest	11	1.0	1.4
Clearcut	2	0.1	0.3
Urban	0	0.0	0.0
TOTAL	1151	--	7.5

Table 5f. 2004 land cover values for private property within Grand Bay-Banks Lake (GBBL) ecosystem. Overall % is (Area of land cover X on private property)/(Total area of land cover X in GBBL) x 100.

Land Cover Class	Area (ha)	% by Owner	Overall %
Open Water	84	1.0	20.7
Herbaceous/Marsh	207	2.4	21.0
Scrub/Shrub	202	2.4	14.5
Forested Wetland	1161	13.7	35.6
Agriculture	2556	30.2	99.6
Pine Plantation	2679	31.6	68.0
Forest	622	7.3	73.6
Clearcut	422	5.0	70.6
Urban	538	6.3	38.9
TOTAL	8471	--	54.9

Table 6a. Land cover change (%) of open water within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s to 2004. T_0 is the earliest date for each time period.

	Total Ha at T_0	**Open Water**	**Herbaceous/ Marsh**	**Scrub/ Shrub**	**Forested Wetland**	**Agriculture**	**Woodland**	**Pine Plantation**	**Forest**	**Evergreen Hammock**	**Clearcut**	**Urban**
1940s-1967	565	90.1	0.2	0.0	9.2	0.0	0.0	0.3	0.0	0.0	0.1	0.1
1967-1983	642	82.1	16.5	0.0	1.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0
1983-1988	566	99.2	0.5	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1988-1993	618	75.8	12.5	2.1	7.0	0.4	0.0	0.6	0.2	0.0	0.2	1.1
1993-2004	508	74.0	24.3	0.3	0.7	0.4	0.0	0.1	0.1	0.0	0.0	0.1

Table 6b. Land cover change (%) of herbaceous/marsh within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s to 2004. T_0 is the earliest date for each time period.

	Total Ha at T_0	**Open Water**	**Herbaceous/ Marsh**	**Scrub/ Shrub**	**Forested Wetland**	**Agriculture**	**Woodland**	**Pine Plantation**	**Forest**	**Evergreen Hammock**	**Clearcut**	**Urban**
1940s-1967	1550	3.5	56.5	26.6	12.8	0.0	0.0	0.5	0.0	0.0	0.0	0.0
1967-1983	1403	0.4	68.4	27.6	3.5	0.0	0.0	0.1	0.0	0.0	0.1	0.0
1983-1988	1126	2.5	95.5	0.5	1.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0
1988-1993	1162	0.4	58.6	33.0	7.2	0.0	0.0	0.5	0.1	0.0	0.0	0.1
1993-2004	829	0.6	94.3	1.0	3.0	0.0	0.0	0.4	0.1	0.0	0.7	0.0

Table 6c. Land cover change (%) of forested wetland within Grand Bay-Banks Lake (GBBL) ecosystem from 1940s to 2004. T_0 is the earliest date for each time period.

	Total Ha at T_0	**Open Water**	**Herbaceous/ Marsh**	**Scrub/ Shrub**	**Forested Wetland**	**Agriculture**	**Woodland**	**Pine Plantation**	**Forest**	**Evergreen Hammock**	**Clearcut**	**Urban**
1940s-1967	3762	1.6	4.8	6.7	75.3	2.5	1.2	5.3	1.6	0.0	1.1	0.1
1967-1983	3655	0.4	0.3	0.3	87.3	1.0	0.0	4.9	0.3	0.0	4.6	0.7
1983-1988	3427	0.6	0.2	0.5	96.0	0.1	0.0	1.0	0.5	0.0	1.1	0.0
1988-1993	3331	0.5	0.9	0.9	89.1	0.3	0.0	2.7	4.5	0.0	0.9	0.1
1993-2004	3563	0.2	1.1	0.5	87.8	0.3	0.0	2.5	0.5	0.0	6.9	0.2

Table 7 (a-d). Land cover change (%) within Grand Bay from a) 1967-1983, b) 1983-1988, c) 1988-1993 and d) 1993-2004.

a) Change from 1967 - 1983 (%)

1967-1983	Total Ha 1967	Open Marsh	Herbaceous/Marsh	Forested Wetland
Open Marsh	56	91.0	8.8	0.2
Herbaceous/Marsh	299	26.5	72.5	1.1
Forested Wetland	8	0.9	6.3	92.8

b) Change from 1983 – 1988 (%)

1983-1988	Total Ha 1983	Open Marsh	Herbaceous/Marsh	Forested Wetland
Open Marsh	127	97.3	2.2	0.5
Herbaceous/Marsh	219	2.3	95.1	2.5
Forested Wetland	10	1.1	3.4	95.5

c) Change from 1988 – 1993 (%)

1988-1993	Total Ha 1988	Open Marsh	Herbaceous/Marsh	Forested Wetland
Open Marsh	126	49.6	49.6	0.8
Herbaceous/Marsh	203	18.3	80.5	1.2
Forested Wetland	15	2.0	13.0	85.0

d) Change from 1993 – 2004 (%)

1993-2004	Total Ha 1993	Open Marsh	Herbaceous/Marsh	Forested Wetland
Open Marsh	101	68.4	31.4	0.2
Herbaceous/Marsh	230	31.6	63.9	4.5
Forested Wetland	16	6.2	1.7	92.1

Table 8(a-e). Land cover change (%) within Moody Bay from a) 1940s-1967, b) 1967-1983, c) 1983-1988, d) 1988-1993 and e) 1993-2004.

a) Change from 1940s-1967 (%)

1940-1967 (%)	Total Area 1940 (ha)	Open Water	Herbaceous /Marsh	Scrub/ Shrub	Forested Wetland	Agriculture	Woodland	Forest	Pine Plantation	Clearcut	Urban
Open Water	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Herbaceous/Marsh	9	0.0	65.3	0.0	30.8	0.0	0.0	0.0	3.9	0.0	0.0
Scrub/Shrub	352	0.0	50.8	12.2	29.1	0.0	0.0	0.0	7.9	0.0	0.0
Forested Wetland	153	0.2	0.0	0.0	66.3	0.1	0.0	0.0	28.7	4.5	0.3
Agriculture	70	0.0	0.0	0.0	4.3	61.5	0.0	0.0	4.5	29.8	0.0
Woodland	163	0.0	0.0	0.0	2.7	7.4	0.0	2.5	73.0	1.6	12.8
Forest	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pine Plantation	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clearcut	205	0.1	1.6	0.0	16.7	0.1	0.0	0.0	53.6	20.8	7.2
Urban	190	0.0	0.0	0.0	0.1	0.0	0.0	0.0	5.1	1.2	93.6

b) Change from 1967-1983 (%)

1967-1983 (%)	Total Area 1967 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Agriculture	Woodland	Forest	Pine Plantation	Clearcut	Urban
Open Water	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Herbaceous/Marsh	188	0.0	21.1	78.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub/Shrub	43	0.0	0.0	89.5	10.3	0.0	0.0	0.0	0.2	0.0	0.0
Forested Wetland	249	0.2	0.1	0.4	84.2	0.0	0.0	0.0	14.2	0.8	0.0
Agriculture	56	0.0	0.0	0.0	0.0	87.5	0.0	0.0	12.5	0.0	0.0
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Pine Plantation	315	0.3	0.0	6.0	5.5	1.9	0.0	0.0	80.3	5.2	0.8
Clearcut	75	0.3	1.7	0.0	0.0	0.0	0.0	0.0	58.6	33.1	6.3
Urban	214	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.6

c) Change from 1983-1988 (%)

1983-1988 (%)	Total Area 1983 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Agriculture	Woodland	Forest	Pine Plantation	Clearcut	Urban
Open Water	3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Herbaceous/Marsh	40	0.0	95.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub/Shrub	208	0.0	11.3	82.1	6.6	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	231	0.0	0.0	0.0	99.1	0.0	0.0	0.0	0.7	0.2	0.0
Agriculture	55	0.0	0.0	0.0	0.0	98.5	0.0	0.0	0.0	1.5	0.0
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pine Plantation	345	0.2	0.0	0.0	0.2	0.1	0.0	0.0	92.6	2.4	4.5
Clearcut	43	0.0	0.0	0.0	0.1	0.0	0.0	0.0	12.1	67.8	20.1
Urban	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	86.9

d) Change from 1988-1993 (%)

1988-1993(%)	Total Area 1988 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Agriculture	Woodland	Forest	Pine Plantation	Clearcut	Urban
Open Water	4	0	0	52	1	1	0	0	15	7	23
Herbaceous/Marsh	62	1	13	86	0	0	0	0	0	0	0
Scrub/Shrub	173	0	1	87	12	0	0	0	0	0	0
Forested Wetland	243	0	0	4	93	0	0	0	3	0	0
Agriculture	55	0	0	0	1	79	0	0	15	5	0
Woodland	0	0	0	0	0	0	0	0	0	0	0
Forest	0	0	0	0	0	0	0	0	0	0	0
Pine Plantation	355	0	1	11	0	0	0	6	78	3	1
Clearcut	39	0	0	0	6	0	0	19	59	15	1
Urban	215	0	0	0	0	0	0	0	7	1	92

e) Change from 1993-2004 (%)

1993-2004 (%)	Total Area 1993 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Agriculture	Woodland	Forest	Pine Plantation	Clearcut	Urban
Open Water	4	46.8	21.6	22.1	1.6	0.0	0.0	0.0	2.6	5.3	0.0
Herbaceous/Marsh	9	0.0	70.3	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub/Shrub	215	0.0	5.9	91.7	1.8	0.0	0.0	0.0	0.6	0.0	0.0
Forested Wetland	288	0.0	0.1	1.1	95.7	0.0	0.0	0.1	2.2	0.8	0.0
Agriculture	44	0.8	0.0	0.0	0.0	98.3	0.0	0.2	0.7	0.0	0.0
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	30	0.0	0.0	0.0	0.0	0.2	0.0	81.0	11.1	5.8	2.0
Pine Plantation	331	0.0	0.0	0.0	0.9	1.6	0.0	4.1	81.8	8.2	3.4
Clearcut	23	0.0	0.2	48.0	0.1	0.0	0.0	10.6	0.0	41.1	0.0
Urban	202	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	99.6

Table 9(a-e). Land cover change (%) within Rat Bay from a) 1940s-1967, b) 1967-1983, c) 1983-1988, d) 1988-1993 and e) 1993-2004.

a) Change from 1940s-1967 (%)

1940s-1967 (%)	Total Area 1940s (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Woodland	Forest	Pine Plantation	Evergreen Hammock	Clearcut	Urban
Open Water	14	13.4	0.0	0.2	84.5	0.3	0.0	0.0	0.0	1.7	0.0
Herbaceous/Marsh	74	0.0	32.1	29.7	33.9	0.1	0.0	4.1	0.0	0.0	0.0
Scrub/Shrub	53	5.7	6.3	15.8	72.2	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	333	5.0	4.9	1.2	82.6	3.9	0.0	0.8	0.1	1.4	0.0
Woodland	206	0.0	0.1	0.0	3.7	90.7	0.0	5.3	0.0	0.2	0.0
Forest	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pine Plantation	7	0.6	0.0	0.0	35.2	0.0	0.0	64.2	0.0	0.0	0.0
Evergreen Hammock	61	0.0	0.0	0.0	18.7	0.0	0.0	0.0	81.3	0.0	0.0
Clearcut	79	0.3	0.0	1.9	30.9	45.9	0.0	3.2	17.4	0.4	0.0
Urban	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

b) Change from 1967-1983 (%)

1967-1983 (%)	Total Area 1967 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Woodland	Forest	Pine Plantation	Evergreen Hammock	Clearcut	Urban
Open Water	22	99.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Herbaceous/Marsh	44	3.4	94.4	0.0	0.1	0.0	0.0	2.1	0.0	0.0	0.0
Scrub/Shrub	36	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	397	0.0	0.3	0.0	95.4	0.0	0.0	3.8	0.1	0.5	0.0
Woodland	240	0.0	0.0	0.0	0.2	0.0	1.5	96.1	0.0	2.1	0.0
Forest	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pine Plantation	25	0.0	0.0	0.0	0.6	0.0	0.0	99.4	0.0	0.0	0.0
Evergreen Hammock	63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.9	1.1	0.0
Clearcut	6	0.0	43.1	0.0	0.4	0.0	0.0	0.0	0.0	56.5	0.0
Urban	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

c) Change from 1983-1988 (%)

1983-1988 (%)	Total Area 1983 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Woodland	Forest	Pine Plantation	Evergreen Hammock	Clearcut	Urban
Open Water	23	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Herbaceous/Marsh	45	61.4	36.3	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0
Scrub/Shrub	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	417	1.6	0.2	0.0	97.1	0.0	0.0	0.0	0.0	1.2	0.0
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	4	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Pine Plantation	272	1.4	0.9	0.0	0.2	0.0	12.0	16.0	0.0	69.5	0.0
Evergreen Hammock	63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Clearcut	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	96.0	0.0
Urban	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

d) Change from 1988-1993 (%)

1988-1993 (ha)	Total Area 1988 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Woodland	Forest	Pine Plantation	Evergreen Hammock	Clearcut	Urban
Open Water	61	39.3	41.6	0.0	14.6	0.0	0.0	0.1	0.0	0.0	4.4
Herbaceous/Marsh	19	8.3	62.6	0.1	20.1	0.0	0.0	3.9	0.0	0.0	5.0
Scrub/Shrub	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	404	0.3	0.1	0.0	98.6	0.0	0.0	0.7	0.0	0.0	0.3
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	36	0.0	0.9	0.0	1.4	0.0	52.7	33.7	0.0	0.0	11.2
Pine Plantation	43	0.1	0.2	0.0	5.4	0.0	0.0	92.4	0.0	0.0	1.9
Evergreen Hammock	63	0.0	0.0	0.0	3.9	0.0	0.0	0.0	96.1	0.0	0.0
Clearcut	205	0.8	3.6	0.1	1.4	0.0	2.3	24.5	0.3	6.0	61.0
Urban	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

e) Change from 1993-2004 (%)

1993-2004 (%)	Total Area 1993 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland	Woodland	Forest	Pine Plantation	Evergreen Hammock	Clearcut	Urban
Open Water	28	17.4	79.7	0.0	1.2	0.0	0.0	0.0	0.0	0.0	1.7
Herbaceous/Marsh	45	0.5	97.9	0.0	1.3	0.0	0.0	0.1	0.0	0.0	0.3
Scrub/Shrub	0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forested Wetland	419	0.0	0.3	0.0	99.5	0.0	0.0	0.2	0.0	0.0	0.0
Woodland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	24	0.5	0.0	0.0	0.0	0.0	98.9	0.2	0.0	0.0	0.5
Pine Plantation	120	0.0	0.0	0.0	1.6	0.0	0.0	97.0	0.0	0.9	0.5
Evergreen Hammock	61	0.0	0.0	0.0	5.6	0.0	0.0	0.0	94.4	0.0	0.0
Clearcut	12	0.0	0.0	0.0	0.0	0.0	0.0	88.2	0.0	11.8	0.0
Urban	135	0.1	3.4	0.3	0.0	0.0	1.0	0.0	0.0	0.0	95.2

Table 10(a-e). Land cover change (%) within Oldfield Bay from a) 1940s-1967, b) 1967-1983, c) 1983-1988, d) 1988-1993 and e) 1993-2004.

a) Change from 1940s - 1967 (%)

1940s-1967	Total Area 1940s (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland
Open Water	115	95.3	1.2	0.0	3.5
Herbaceous/Marsh	875	3.0	50.4	44.8	1.8
Scrub/Shrub	496	0.0	31.6	59.7	8.6
Forested Wetland	413	0.4	30.5	58.0	11.1

b) Change from 1967 - 1983 (%)

1967-1983	Total Area 1967 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland
Open Water	139	97.4	0.2	0.5	1.9
Herbaceous/Marsh	721	0.3	62.2	33.5	4.0
Scrub/Shrub	929	0.3	5.1	87.8	6.8
Forested Wetland	109	1.8	1.0	2.1	95.0

c) Change from 1983 – 1988 (%)

1983-1988	Total Area 1983 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland
Open Water	144	99.2	0.8	0.0	0.0
Herbaceous/Marsh	498	0.1	99.2	0.7	0.0
Scrub/Shrub	1072	0.1	4.6	95.4	0.0
Forested Wetland	197	0.0	1.1	0.0	98.9

d) Change from 1988 – 1993 (%)

1988-1993	Total Area 1988 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland
Open Water	140	54.8	32.6	8.0	4.6
Herbaceous/Marsh	545	0.3	32.3	60.1	7.2
Scrub/Shrub	1017	0.0	0.2	78.5	21.3
Forested Wetland	195	0.6	1.3	4.3	93.8

e) Change from 1993 – 2004 (%)

1993-2004	Total Area 1993 (ha)	Open Water	Herbaceous/ Marsh	Scrub/ Shrub	Forested Wetland
Open Water	80	48.3	50.4	0.0	1.3
Herbaceous/Marsh	224	0.2	98.5	0.8	0.4
Scrub/Shrub	1142	0.0	0.7	98.5	0.7
Forested Wetland	445	0.0	0.5	1.2	98.3

APPENDIX A: LIST OF DELIVERABLES

- **Historic and Current Photographs (5 DVDs)**
    - GBBL 40s photos DVD
    - GBBL 67 photos DVD
    - GBBL 83 photos DVD
    - GBBL 88 photos DVD
    - GBBL 93-04 photos DVD

All photographs were taken during leaf off. We renamed the file names for the aerial photographs so that they are listed numerically from left to right, starting in the upper left hand corner of the study area. Each file name consists of a number and the appropriate year. Sometimes when there was a lot of overlap between photos, we renamed the photos as 1a, 1b or 1c. See Misc. section for more information.

All other data are stored on 1 DVD: GBBL Land Cover Data and Analyses

- **Data in ArcMap Personal Geodatabases**

The following files are in ArcMap personal geodatabases. All of these files also have metadata files associated with them.

GB_BL Pre-1980s geodatabase

- GB_BL_1940s
    - Cover_1940s
    - Disturbances_1940s
    - GB_BL_1940s Topology
- GB_BL_1967
    - Cover_1967
    - Disturbances_1967
    - GB_BL_1967_Topology

GB_BL 1980s geodatabase

- GB_BL 1983
    - Cover_1983
    - Disturbances_1983
    - GB_BL_1983 Topology
- GB_BL 1988
    - Cover_1988
    - Disturbances_1988
    - GB_BL_1988 Topology

GB_BL Recent geodatabase

- GB_BL 1993
  - Cover_1993
  - Disturbances_1993
  - GB_BL_1993 Topology
- GB_BL 2004
  - Cover_2004
  - Disturbances_2004
  - GB_BL_2004 Topology
- Analysis
  - Study Area
  - GB_BL_Union
  - *see GB_BL Ownership below*

- ## Data Analyses

Carolina Bay comparisons

This folder contains individual folders with data used for Change Analysis for the main Carolina bays: Grand Bay (GB), Moody Bay, Rat Bay, and Oldfield Bay

- In each Carolina bay folder there is:
  - Folder for each year (e.g. GB_67)
    - Shapefile with land cover for Carolina bay and any surrounding area used for change analysis
    - Raster folder
      - Original 50 ft raster created from Carolina bay shapefile
      - "Reclass" folder with another version of the original raster that was reclassified by merging several land cover classes (e.g. Reclass_67)
  - Folder for each time period (e.g. Combine_67_83)
    - Change analysis data produced using COMBINE function. In this example, we combined Reclass_67 and Reclass_83 rasters.
    - We did additional reclassifications to look at key changes in land cover within and/or surrounding the Carolina bay. The reclassified raster data are in folders with names like "Interior_Reclass", and "Marsh_Reclass"

        - Note: There are folders named "CG_Reclass" that should really be named Forested Wetland reclass (for all data analyses we merged cypress-gum—CG—with other forested wetland classes)
    - Excel spreadsheets:
        - Change analysis within each Carolina bay as hectares and % change
        - Worksheets have information explaining 1) values used for the first reclassification where we merged several land cover classes and 2) values used for other reclassifications created to highlight important changes over time.

<u>Change Analysis</u>

This main folder contains data for the Change Analysis of the entire GBBL study area.

- Folder for each year (e.g. Change 1967)
    - Shapefile with land cover for the entire GBBL study area. Data were converted into shapefile from original feature class (e.g. Cover_1967 in the Pre-1980s geodatabase)
    - Raster folder with original 50 ft raster of entire GBBL study area.
    - Reclass folder with another version of the original raster that was reclassified by merging several land cover classes
- Folder for each time period (e.g. Combine_40_67)
    - Change analysis data produced using COMBINE function. In this example, we combined Reclass_40 and Reclass_67 rasters.
    - We did created additional reclassified rasters to highlight changes in key wetland features
        - FW_Reclass (forested wetland)
        - Marsh_Reclass (herbaceous/marsh)
        - Water_Reclass (open water)
- "GB_BL_Change" Excel spreadsheet:
    - Change analysis as hectares and % change.

- Worksheets have information explaining 1) values used for the first reclassification where we merged several land cover classes and 2) values used for other reclassifications created to highlight important changes over time.

GB_BL Ownership

- "GB_BL_Ownership" Excel spreadsheet with analysis of land cover trends according to management unit (ownership)
- Data stored in "GBBL_Recent" geodatabase in "Analysis" feature dataset as "GB_BL_Union"
    - Used UNION function on "Ownerships" shapefile (obtained from Moody AFB) and Cover_2004 feature class
    - Polygons with no known owner were classified as Private in our calculations in Excel

Total Area

This folder contains "GB_BL_Area" Excel spreadsheet :

- Total area per year for **all** mapping classes as well as merged classes for data analysis
- Area reported in hectares, acres and percentage
- Also has summary of total linear features per year

Wetland Outlines

This folder contains wetland outlines that were used in our Change Analysis maps

- Folder for each year (e.g. 1940s_outline)
    - Shapefile with land cover for all wetland classes
    - Our definition of wetland included: bottomland hardwood, bottomland hardwood (riparian), cypress-gum swamp, cypress-gum swamp (mixed), cypress-gum swamp (riparian), evergreen forested wetland, herbaceous/marsh, open water, scrub/shrub.

Miscellaneous information re: GBBL study area

- "GBBL Aerial Photography" Excel spreadsheet
  - Lists original file name, photo scale, data source, and type of photograph
- "Potential GBBL Ecosystems" Excel spreadsheet
  - Lists land cover classes used for mapping and potential ecological systems and associations
  - Wasn't able to compile this information for all classes
- "2-17-06 Valdosta Photos" folder
  - Includes pictures from hike with A. McGee into marsh area in southwestern section of Oldfield Bay and example of urbanization within GBBL study area

Grand Bay-Banks Lake
Desired Future Ecological Condition Workshop

Date: June 9-10, 2004
Location: Grand Bay Education Center, Valdosta, GA

Statement of Need

A Conservation Area Plan (CAP) for Grand Bay-Banks Lake was completed in 2003. The CAP establishes conservation targets and includes a threats analysis and strategies to mitigate the threats on the conservation targets. The GIS-based analysis identified stresses and sources of stress for each of six conservation targets. From this analysis, priority conservation strategies were developed to mitigate or abate these threats. One of the top-ranked strategies was to enhance or restore essential habitat for species of special concern. In order to accomplish this objective, additional information is needed to define specific management objectives for Carolina bays and wading birds. In June 2004, a workshop was organized to bring together experts to begin to address this need by defining the desired future ecological conditions (DFCs) for the Carolina bays and wading birds at Grand Bay-Banks Lake. DFCs are an expression of the range of ecological conditions preferred for a population, community or ecological system, attainable within the human context over a selected period of time, and used to guide management, restoration and land use.

Attendees

Alison McGee, Christi Lambert, Mal Hodges, Mary Davis- GA TNC
Mike Leslie, SC TNC
Rob Sutter, TNC, Southeast Division
Sarah Aicher, Skippy Reeves, USFWS
Wes Abler, Tip Hon, DNR WRD
Shan Cammack, John Jensen, DNR WRD-NWNHS
Bruce Connell , Forester at Moody Air Force Base
John Mitchell, Branch Chief at Moody Air Force Base
Greg Lee, Manager of Resources Branch at Moody Air Force Base
Kay Kirkman, JW Jones Ecological Research Center
Neda Hon, DNR Educational Coordinator
Can Denizman, Geologist, Hydrologist, GIS at Valdosta State University
Steve Vives, Professor, GA Southern University

Review of Conservation Area Plan (Background)

The Grand Bay-Banks Lake Stewardship Partnership is a collaboration among Moody Air Force Base, The Nature Conservancy, Georgia Department of Natural Resources, U.S. Fish and Wildlife Service, and numerous private landowners. The mission of the partnership is to develop and implement a voluntary and cooperative stewardship plan for the Grand Bay-Banks Lake Ecosystem. The goals of the plan will ensure the long-term viability of the native plants and animals, and ensure the integrity of the ecosystems, while providing for compatible human uses.

The 100,000 acres that encompass the Grand-Bay-Banks Lake ecosystem contain an abundant diversity of relatively undisturbed aquatic and terrestrial habitats. These unique communities include excellent examples of longleaf pine flatwoods, Carolina Bays, and evergreen hardwood hammocks. The Nature Conservancy has identified these natural communities as priority conservation targets. The remaining three conservation targets are wading birds, migratory birds and riverine aquatic systems.

The ecological footprint of Grand Bay-Banks Lake is approximately 100,000 acres. The focus of this workshop is the wetland complex (approximately 17,760 acres).

History of Grand Bay-Banks Lake (Tip Hon)
The swamp burned in 1956-57. It was logged 1910-1920, leaving lots of slash on the ground. There was a big fire in 1924-25 that burned for months, consuming peat and creating open water. Peat was burned down to expose tree roots, according to anecdotal evidence. Today, there is an average of about 18 inches of peat in the bays.

Current management is keeping water levels at historical levels, but for a longer period. The dam at Banks Lake was installed in the 1800's. The previous landowner of Banks Lake would lower the water levels periodically. Locals would take advantage of the excellent fishing at this time. Tip Hon conducted an elevational study on part of the system.

Limited prescribed burning has been conducted. In December 1987, 1,500 acres of Old Field Bay was burned. DNR had to work with 22 landowners and install miles of breaks. It was a good surface burn but did not consume peat. Water levels were manipulated to retard resprouting. Through successional changes, the system is losing the emergent marsh and floating mat communities. Shrub communities are increasing in extent.

Desired Future Ecological Condition
For the purposes of this workshop, we defined desired future ecological condition (or "desired future condition"- DFC) as a clearly articulated, broad to specific expression of ecosystem conditions, attainable within the human context over the next fifty years, used to guide management and land use. Most simply, a desired future condition is a management goal, the conditions that management is attempting to obtain over a set period of time.

Desired future conditions:
1. provide a vision of future conditions that can be communicated to staff, colleagues, stakeholders and the public (resulting in a sense of purpose and focused creativity for staff);
2. guide conservation and management actions within the human context, and when the vision includes two or more conservation targets, it integrates management across those targets;
3. provide a framework for identifying short-term management objectives and benchmarks;
4. provide spatial and temporal priorities for management and conservation (allowing for the effective and efficient use of time, talent and tools); and
5. integrate monitoring and adaptive management into natural resource management.

There are three components to a desired future condition. The first is the **condition** that is desired for an ecological system, landscape, community or population. By condition, we mean the abundance, structure, composition, function and heterogeneity of the system, community or species we want to conserve. For systems and communities, the significant conditions are vertical and horizontal structure of the vegetation and community or species composition. For species, the significant conditions are abundance (size of each population and total number of populations), population structure (comparative abundance of different age classes) and the habitat in which the species occurs. The condition must be viable and sustainable and attainable within the human context.

Secondly, a desired future condition needs a **spatial** setting. Where on the ground is the desired future condition to be maintained, managed and/or restored? Specifically, this is the spatial relationship among populations and the spatial extent and configuration of communities and ecological systems.

Identifying a spatial extent using ecological criteria is essential for delineating land use within a land management area. It also is essential for assessing feasibility and program costs. The spatial area may be where the focal conservation target currently occurs, the historic extent of the focal conservation target, or a spatial extent as is related to the human context.

Lastly, conservation goals need to be set within a realistic **time frame**. For Grand Bay-Banks Lake, it was decided that this period would be 50 years.

A very important characteristic of a desired future condition is that it reflects what is attainable within the current **human context**. This includes the context of land use, social and political atmosphere, mission context and the limits of funding for management and conservation. While one may prefer to restore a naturally functioning ecosystem across a large landscape, such a desired future condition is rarely possible. Thus the process of identifying a desired future condition has to guide natural resource management within the current human context.

Description of Workshop

The objectives of this workshop were: 1) to develop desired future conditions for the focal conservation targets (Carolina bays and wading birds), 2) to develop recommendations to guide future land management (focused on the fire management and hydrologic regime of this ecological system) and 3) to develop preliminary measures of success (to determine if management recommendations are successful). Two breakout groups focused on fire and hydrology were formed to accomplish these tasks. Because the populations of wading birds are dependant on the habitat within Carolina bays, discussion focused on the management of Carolina bays.

Task #1: Define desired ecological conditions; identify information needs/knowledge gaps (Fire)

Questions for the Fire Breakout Group:
If possible, please provide published references or source of expert opinion for each and note information/research needs.

1. What range of fire frequency maintains the structure and composition of Carolina Bay wetlands? How is this fire frequency different along the hydrologic gradient from dry sandhills to the wettest part of the Carolina Bay wetlands? What is the current fire frequency across the conservation area?
2. What is the natural fire intensity for fire during different seasons? What fire intensity is needed to maintain the structure and composition of Carolina Bay wetlands? What is the current fire intensity of fires within the conservation area?
3. What is the seasonality of fire in this region? Is there a difference between the season of highest natural fire ignition and the season of the greatest natural spatial extent of fire…? How important is it to burn within natural range of seasonality? What seasons of burn are used currently at this conservation area?
4. What were the natural spatial fire extent/natural fire units in this landscape? How does current fire management units compare with the natural units? How important is it to manage fire at a scale closer to the natural fire units?
5. What landscape context would maintain the ecosystem processes in these wetlands? How does the current landscape context influence these ecosystem processes? What landscape context is needed for management and to mitigate off-site threats?

<u>Desired Ecological Condition: Carolina bays</u>

- Fire frequency is unknown. Zones of vegetation have different fire frequencies. Tip Hon estimates that the interior of bay burned every 25-50 years, savanna areas every 7-20 years.
- We know these Carolina bays burned. Fire probably came from the uplands, probably burned for long time, probably burned during the growing season; those sweeping through the bay probably had high intensity.
- Fires feathered into the bay to different levels resulting in a mosaic burn.
- Peat fires, necessary to create open water, emergent marsh, and floating mat communities, are probably even less frequent—maybe more than 100 year return interval.
- Current fire management goal is to attempt high intensity dormant season burns.
- We are not confident that it will be possible to achieve desired future ecological condition (DFC) given the constraints.
- DFC requires growing season burns (although these are not feasible given constraints).
- Ironically the logging of cypress made more early succession habitat
- Can we achieve the desired ecological condition without fire?
- Landscape context makes it tricky with MAFB and nearby cities- current landscape context disrupts ecological processes
- Should develop a fire use plan with contingencies to take advantage of wildfires. Get Okefenokee's fire plan, look at it from a risk-based perspective and as saving money.
- Moody AFB (MAFB) helps protect the wetlands system with their zoning.
- We should consider working with the county on zoning and on conservation easements on buffer areas. The most important areas to target are along the east and southeast. This will benefit the burn program due to the prevailing winds and the water quality by keeping septic tanks out.

- Consider encouraging county to pass a right-to-burn ordinance to protect against future restrictions. There are air quality issues with prescribed burning and not wildfires. Valdosta may be considered in a non-attainment area under the Clean Air Act.
- Long-term research needs: how seasonality of fire affects composition and succession; look into the historical fire frequency
- low confidence on all of this except for seasonality (2) and spatial (3)

Long-term research needs: How does the seasonality of fire affect composition and succession? Examine the historical fire frequency.

Task #2: Define management options to reach Desired Ecological Condition (Fire break-out group)

Desired ecological condition: Implement appropriate fire regime to increase the percentage of early succession structure and composition and reduce the extent of shrub communities. The relative proportion of these communities is changing in the absence of fire.

Management Option #1: Prevent traditional suppression activities in Carolina bays to reduce extent of shrub bogs

- Work with GFC to develop "fire-wise" communities program (eg. "Fire in the Ecosystem" week at MAFB)
- Work with GFC and major landowners to prepare a Pre-attack Plan (may include active management of fires to hasten burn-out- actions spelled out in plan). This will save money and enhance firefighter safety.
- Pros:
  - Model already in place at Okefenokee, Wesley Langdale on the Board (GOAL: Greater Okefenokee Association of Landowners)
  - Wildfire will be more acceptable than prescribed fire
  - Natural fire may be more effective at producing DEC
- Con/Hurdles
  - Lack of education
  - Impact to MAFB mission
  - Smoke concerns
  - Risk of upland fire impacting residential areas

Management Option #2: Eliminate breaks at margin of bays, burn into bays from upland
Management Option #3: Burn from upland into bays in April-June (change season of burn)
Note: Options 2 and 3 were discussed together

- Pros:
  - May reduce shrub bog extent
  - Better hardwood control
  - Provides more diverse habitats for fauna
  - Reduced winter blackbird habitat
- Cons/Hurdles:
  - GFC policy is to have fire out by 5 pm
  - Liability of smoke
  - Negative public opinion (bird/wildlife death, smoke, etc.)

Management Option #4: Mechanical and/or chemical control/treatment to reduce extent of shrub bog and bay swamp

- Remove shrub bog with tracked vehicles on mats w/ cutter head, followed by spray. This may increase hydroperiod to help create/maintain emergent marsh.
- Investigate market for products to encourage removal of fetterbush (artificial ficus tree stems)
- Aerial spraying of shrubs followed by burning
- Pros:
    - Don't have to rely on approval to burn for chemical treatment
    - May extend conditions under which we can burn (due to slash on the ground)
- Cons/Hurdles:
    - Expensive
    - Damage to wetlands from equipment
    - Increased fire danger due to excessive fuels
    - Military mission reduces access to areas to conduct treatment

Management Option #5: Conduct prescribed fire in wetlands under conditions and season necessary to create DEC (high-intensity fire during drought conditions)

- Aerial ignition w/ grid pattern
- May be a long-term goal to work toward, using other techniques in interim
- Pro: Best way to achieve DEC (more emergent marsh/floating mat)
- Cons/Hurdles:
    - Short window of opportunity
    - Difficult to get permit
    - Long-term smoke management
    - Public opinion
    - Military mission
    - Fire/smoke control activities over long period- expensive, many resources expended
    - High cost of conducting prescribed burn

Task #1: Define desired ecological conditions; identify information needs/knowledge gaps (Hydrology)

If possible, please provide published references or source of expert opinion for each and note information/research needs.

Questions for the Hydrology Breakout Group:

1. What is the range of hydrologic conditions that would have naturally been seen in these Carolina Bay wetlands? What were the driving forces that determined these natural hydrologic regimes? What is the current range of hydrologic conditions?
2. What range of hydrologic conditions benefit different species targets that occur in or use these Carolina Bay wetlands? How do the current conditions benefit these different species targets?
3. What was the natural spatial extent that influenced the hydrology of these Carolina Bay wetlands? How does the current spatial extent influence the hydrology?
4. What landscape context would maintain the ecosystem processes in these wetlands? How does the current landscape context influence these ecosystem processes? What landscape context is needed for management and to mitigate off-site threats?

Question 1: Range of Hydrologic Conditions

- Very dry to very wet: 0-4 ft
    - Varied spatially, over long-range drought cycles, annually
    - Most of system would have drained/dried every year

  - Most years some limited basins would have held water through driest seasons
  - Wettest: December-Aug.; Driest: Oct.-Dec., May
- Driving forces:
  - Tropical cyclones would have caused random spikes
  - Thunderstorms can cause spikes of deep water
  - Evapotranspiration
  - Drainage gradient
  - Temperature and precipitation cycles
  - Surface-water run-off

Research Need: Ties between surface and groundwater- connectivity, interchange, etc.

Current Hydrologic Conditions

- Pulses off impervious surfaces create larger spikes from precipitation or funnel water unnaturally
- Longer hydroperiods created in Grand Bay, Dudley Bay and Banks Lake by water control structures- lakes
- Roads through bays divide systems into artificial compartments- interrupts sheet flow

Research Needs: Questions about water quality issues from MAFB e.g. naphtha plume, complex organics, and from subdivisions- eutrophication, cattail marshes, taro indicators; Overall vegetation map, vegetational successional model; changes in vegetational cover have changed evapotranspiration, sheet flow; water monitoring gauges, flow meters; Topo surveys- profiling, flow patterns. References: Monk, Wharton, Frost, Cindy Lofton

Question 2: What hydrology benefits which species?

- For cypress regeneration, need 2-3 yrs drawdown during growing season, every 15-20 yrs.
- Early successional stage marsh for *Neofiber* and sandhill cranes (can't maintain without fire, but can prolong w/ careful hydrologic manipulation
- Biodiversity goes down w/ succession to shrub bog- shrubs grow in floating peat or peat over soil
- Fertilization promotes growth of cypress in rookery
- Sandhill cranes (SACR) are keystone species. They manipulate vegetation in the system by cropping herbs in emergent marshes and floating mats.

Research needs: Effects of: SACR on mats/marshes; flight patterns on SACR movements; ag fields on SACR populations? Historical analysis of peat-determined fire history by age and hydrology

Question 3: Spatial extent

- Watershed is spatial extent- 240' contour is natural break in hydrology

Question 4: Landscape context for hydrology

- Sewage, stormwater, septic systems flow/runoff
- Buffers to system (need to define-are they possible?)
- Planning and education-ways to effect community or for community to affect system
- Roads, runways, ditches funnel water out of or to different parts of system
- Water quality issues
- Succession allows more bird habitat- could be used as bargaining chip w/MAFB
- MAFB affects run-off, pollution, noise

Research needs: Floral and faunal inventory to baseline for invasives; monitor effects of water quality on species of concern and quality and quantity on system

Task #2: Develop management options to achieve Desired Ecological Condition- (Hydrology)

<u>Open Water</u>
Hurdle: Politics with Lakeland- they would fight to keep it open water
Option: Former owner drew down every few years, allowed fish to be harvested
Option: Banks Lake with minimal management should be DEC (Mary)
Option: Drop Banks Lake to 190' above sea level (or 1.5' deep), allow it to fluctuate naturally (Tip)
Option: Move water up and down to manipulate plant communities, avoid shrub bog (Mary)
Comment (Tip): We don't need to change or remove water control structures, just lower levels
Comment: Pro- With connectivity of water, fish could move through the system
Comment: Discussion focused on what may be politically possible, not what we think should be DEC

<u>Shrub Bog vs. Emergent Marsh/Floating Mat</u>
Hurdle: Can't get peat out without fire
Option: Mow shrub layer (or harvest peat?) and then re-flood or burn then re-flood; some combination of vegetation removal, fire and flooding to keep shrubs and thickets at bay
Comment: Easy to sell drawdown of lake for fish management
Option: Herbicide could be another tool in concert with mechanical control, fire and flood to control shrubs and other undesirable woody species
Option: Develop buffers w/ little surface vegetation as fire breaks around burn units (surface fires only)
Comment: Dike around Moody Bay creates obvious habitat break- remove it? Tip- It's water diversion from uplands that is messing up this bay, not dike. We can manipulate flows elsewhere to help normalize flows- low water crossings to equalize water levels
Hurdle: Cannot remove dike because it is used by MAFB
Hurdle: Mowed shrubs re-sprout readily. Re-flooding is not so useful if shrubs are growing in floating peat.
Comment: Pro- mowing can't be outsourced

<u>Cypress/Gum Swamps</u>
Option: Leave it alone, can't manage
Comment: Con- forest is sick (too much blackgum?)
Observation: After flooding for 5-6 years, blackgum die
Option: Let swamp around boardwalk undergo seasonal flooding for several years
Comment: Pro- can protect boardwalk from fire (we do it now)
Comment: Cypress regeneration- needed in some areas, not in others
Hurdle: most of the rim is in private hands
Comment: Pro- blackgum rims acts as excellent firebreak- maybe shouldn't try to convert it to something else

Task #3: Develop preliminary measures of success
- Key Ecological Attributes include factors that determine the condition of the target, including biological composition, biotic interactions and processes, environmental regimes, and landscape structure

- Threshold for Functionality and Viability: Above this threshold either none or some intervention required to maintain attribute ***within*** acceptable range of variation. Below this threshold extensive restoration and major intervention required to restore attribute ***to*** acceptable range of variation

Key Ecological Attribute	Indicator	DEC (Range)	Current (Range)	Threshold (Good/Fair)
Spatial Extent of Emergent Marsh/Floating Mat (EM/FM)	Aerial Extent (of total wetland acreage)	40-60%	TBD	40%
Spatial Extent of EM/FM	Distribution of Aerial Extent	TBD (e.g. 25% increase in Oldfield Bay, 10% increase in Grand Bay)	TBD	
Structure/Succession of EM/FM	% cover of certain woody spp. (*Cephalanthes* ok)	<10%	TBD	25-30%
Composition of EM/FM	Abundance of certain spp. (*Lachnanthes, Carex)*	TBD (Research needed)	TBD	TBD
Abundance of *Neofiber* (FL water rat)	# of houses (1 rat/2 houses)	#/acre?	125 houses (#/acre?)	100 houses
Abundance of *Neofiber*	Distribution of houses			
Abundance of sandhill cranes	Total # overwintering	1500-2000	500	500/yr avg. over 5 yrs.
Abundance of sandhill cranes	Total # of residents (FL sandhill cranes)- nest counts and unison call counts in spring	30-50 pairs	15-20 pairs	15 pairs
Landscape context/ foraging habitat	Ag. Croplands w/in 5 mi radius	Corn, peanut, winter grazing fields desirable		
Quality of EM/FM habitat	% usage of wood duck boxes (nesting success)			
Hydrologic regime	Index of depth, duration, fluctuation and seasonality	TBD for each bay		
Hydrologic regime	Water levels at control points			

Comment/Question (Kay): Emergent marsh and floating mat communities were lumped together for discussion purposes. This may cause problems in implementing strategies and measures of success. Are they equally important? Can they be mapped separately? Is there a mixture (relative proportion) of the two that is desirable?

Conclusions

Workshop participants concluded that if the management of the Grand Bay-Banks Lake ecosystem continues on its current trajectory, GBBL is in danger of losing some of its most important species and natural communities due to successional vegetation changes. Serious hurdles must be overcome to implement management strategies that may be effective in maintaining viable populations of conservation targets such as sandhill cranes and Florida water rats. However, participants felt that it may be possible to create and maintain the habitat these species need through a combination of fire and manipulation of water levels. Preliminary recommendations were developed by the participants. More information is needed to develop specific measures of success, including an assessment of the current extent of emergent marsh and floating mat communities. The Grand Bay-Banks Lake Council will meet in August 2004 to discuss next steps. The Council will discuss implementation of key strategies and will address the information needs identified at the workshop.

Acknowledgements

Thank you to the participants for bringing invaluable expertise to help address critical questions affecting the long-term viability of conservation targets at Grand Bay-Banks Lake. Also, thank you to Neda Hon at Grand Bay Wetlands Education Center for providing the perfect venue for the workshop. Finally, very special thanks go to the Price-Campbell Foundation for providing financial support for this workshop.

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